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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Bethpage, L. I., N. Y.

Grumman

SPECIFICATION

Page: Title and 74

This specification supersedes Specification LSP-310-2B, dated 9-18-63.

No. LSP-310-2C   Date: 4-29-66

PROPELLANT SYSTEM AND THRUST CHAMBER ASSEMBLIES,

REACTION CONTROL SUBSYSTEM

DESIGN CONTROL SPECIFICATION FOR [U]

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Grumman LEM

[redacted]

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SPECIFICATION

Spec. No. LSP-310-2C

Date: 4-29-66

Page: A

Rev.	Date	REVISION DESCRIPTION
A	7-13-63	This specification has been revised to reflect the changes agreed upon with the vendor during subcontract negotiations.
B	9-18-63	This specification has been revised to reflect the changes agreed upon with the vendor during subcontract negotiations and incorporate the recommendations of MSC, Houston, Texas. Specification Control Drawing LSC-310-100 has been replaced by LSC-310-100A.
C	4-29-66	This specification has been revised to incorporate the requirements of Amendments 1 through 6. These changes are indicated by marginal indicia.

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PROPELLANT SYSTEM AND THRUST CHAMBER ASSEMBLIES, REACTION CONTROL SUBSYSTEM DESIGN CONTROL SPECIFICATION FOR

1 SCOPE

1.1 Scope. - This specification outlines the requirements for the Propellant System and Thrust Chamber Assemblies (PS/TCA) to be used on the bipropellant Reaction Control System of the Lunar Excursion Module (LEM), Apollo Spacecraft.

1.2 Classification. - The Propellant System and Thrust Chamber Assemblies shall consist of:

(a) Sixteen (16) radiation cooled thrust chamber assemblies. Each assembly shall consist of a thrust chamber with fuel and oxidizer solenoid valves (thrust chamber valves). The thrust chamber assemblies are grouped in clusters of four and externally mounted on the LEM vehicle.

(b) Instrumentation and filters as required.

NOTE: All propellant lines external to component packages will be provided by Grumman.

2 APPLICABLE DOCUMENTS

2.1 General. - The following documents of the issue in effect January 14, 1963 form a part of this specification only to the extent specified herein:

SPECIFICATIONS

Military

MIL-B-5087	Bonding; Electrical (for Aircraft)

2.1 (Continued)

MIL-S-7742	Screw Threads, Standard, Optimum Selected Series, General Specification for
MIL-P-26539	Propellant, Nitrogen Tetroxide
MIL-P-27402	Propellant, Hydrazine, Unsymmetrical Dimethyl Hydrazine
MIL-C-45662A	Calibration, System Requirements
MIL-W-16878D	Wire, Electrical Insulated, High Temperature

STANDARDS

<u>Military</u>

MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-704	Electrical Power, Aircraft, Characteristics and Use of
MIL-STD-810	Environmental Test Methods for Aerospace and Ground Equipment

<u>MSFC Documents</u>

MSFC Drafting Manual	Section 15
MSFC-PROC-158A	Soldering of Electrical Connections (High Reliability)

2.1 (Continued)

NAA Documents

MC901-0004	Rocket Engine, Bi-Propellant, Service Module Reaction Control

Grumman Documents

LSP-530-001 with Amendment No. 1	Electromagnetic Interference Control Requirements, General Specification for 9-16-63
LSP-310-0001	Cleanliness Level Requirements of Reaction Control Subsystem
LLI-360-1	Grumman Flight Instrumentation Selection List

DRAWINGS

LSC310-116 (latest revision)	Cluster Assembly, RCS Thrust Chamber, Specification Control Drawing for
LSC310-121 (latest revision)	Propellant Pressure Transducer, Specification Control Drawing for
LSC310-122 (latest revision)	Propellant Temperature Transducer, Specification Control Drawing for
LSC310-125 (latest revision)	Propellant Filter, Specification Control Drawing for

2.2 Precedence. - When the requirements of the Purchase Order, this specification and subsidiary specifications, are in conflict, the following precedence shall apply:

(a) Purchase Order - The purchase order shall have precedence over any specifications.

(b) This Specification - This specification shall have precedence over all subsidiary specifications.

2.3 Availability of Documents. - Copies of this specification and other applicable documents referenced herein may be obtained upon request from LEM Program Data Management, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York, Attention: Specifications Group.

3 REQUIREMENTS

3.1 General. -

3.1.1 Drawings and Data Submittal. - All drawings and other data required under this specification shall be submitted in accordance with the purchase order.

3.1.2 Deviations. - When the requirements of this specification and any applicable subsidiary specifications cannot be met the following shall apply:

(a) Deviations shall be noted in the vendor's proposal documents and brought to the attention of Grumman.

(b) Deviations shall require approval by Grumman Engineering prior to incorporation into any component.

(c) Parts containing unauthorized deviations shall be subject to rejection.

3.1.3 Mock-up. - A full scale metal mock-up of all components shall be provided for assembly at Grumman. Used components or actual component housings shall be used wherever possible. The mock-up shall be kept current with approved changes throughout the contract, unless otherwise authorized by Grumman.

3.2 Performance. -

3.2.1 Thrust Chamber Assembly. - The TCA shall meet the performance requirements of NAA Specification MC 901-0004.

3.2.1.1 Attitudes. - The (PS/TCA) when pressurized per 3.4.4 shall start, operate as required and shutdown in any attitude under the flight maneuver loads and conditions specified herein, and under zero gravity conditions.

3.2.1.2 Ascent Interconnect. - The PS/TCA shall meet all the requirements of this specification when supplied with propellants from the LEM Ascent Stage Propulsion System. These propellants conform to the requirements of paragraphs 3.4.1.1 and 3.4.1.2 and will be supplied at a temperature of $70^{\circ}F \pm 30^{\circ}$ and a nominal static pressure of 188 ± 5 psia. Maximum dynamic pressure loss across the interconnect components shall not exceed 5 psi. The dynamic pressure characteristics will be equivalent to that of the RCS pressurization system.

3.2.1.3 Duty Cycle. - The typical mission duty cycle is shown in Table V.

3.2.2 Life. -

3.2.2.1 Operating Life. - The PS/TCA shall be capable of accomplishing the typical mission duty cycle of Table V at any time within a period of 14 days under the environmental and load conditions specified in Table II, Part (c). During the pre-launch period, the PS/TCA shall be serviced and tested in accordance with approved procedures and shall require no additional servicing during the 14 days operational period..

3.2.2.2 Thrust Chamber Operating Life. - The Thrust Chamber Operating Life shall meet the requirements of NAA Specification MC901-0004.

3.2.2.3 Storage Life. - The PS/TCA shall meet the requirements of this specification after being subjected to permanent storage for five years with necessary periodic maintenance. Storage life is a design criterion only and does not require demonstration. No permanent weight shall be added to the PS/TCA to meet these requirements.

3.2.2.4 Frequency of Operation. - The requirements of this specification shall be met after a non-operating period of 2 years following acceptance test. The vendor shall indicate storage limitations of proposed hardware and recommended protective measures.

3.3 Design. -

3.3.1 General. - The PS/TCA shall be designed to meet the environmental and load criteria of Table II in addition to the self generating loads incurred in meeting the specified performance. Design load envelopes shall be established by superposition of rationally deduced critical loads for all ground and operational conditions and shall include cumulative effects, as well as simultaneous loadings.

3.3.1.1 Safety Factor. - Factors of safety must be applied to the levels of Table II as well as to the self-generated loads of the PS/TCA. Rational allowance shall be made and incorporated in these loads for stress concentrations, fatigue loading and dynamic response. For steady loads or accelerations and for shock loading, the ultimate factor of safety is 1.5. For vibratory loads the limit factor of safety is 1.3 for g or D.A. and (1.3) for g^2/cps. The ultimate factor of safety is 1.5 for g or D.A. and (1.52) for g^2/cps. For pressurized units such as the control valves and valve actuators, the proof factor is 2.00 and the ultimate factor is 3.00. For combined loadings, the ultimate factor of safety is 1.5 except that when pressure effects are relieving, pressure shall not be used.

3.3.1.1.1 Vibration Amplification Factor. - The vibration levels specified in Table II are inputs from the LEM primary structure. The modifying effects of secondary structure, including the Grumman TCA cluster support, must be considered in determining vibration levels for design of components and assemblies subjected to these levels. The Grumman cluster support will have a fundamental resonance between 20 cps and 60 cps. Grumman will furnish sufficient structural data for the Grumman cluster supports to enable the vendor to calculate the vibration loads on the TCA cluster mount. The vendor shall establish, with Grumman approval, the design vibratory levels for the TCA firing conditions. These shall be at levels which will include at least 98% of the acceleration spectral density levels over a frequency range of 15-2000 cps. The vibration amplification factor, as a result of the vibration inputs to the engine, shall not exceed a value of 10, where not already limited to a lower value by other design requirements. This amplification factor is defined as the total displacement of any point on the item under test, divided by the displacement of the input device. These requirements shall be considered during development testing of the engine. In cases where this requirement appears difficult to accomplish, Grumman shall be consulted for direction. The vibrational motion amplification factor on any portion

3.3.1.1.1 (Continued)

of the equipment shall be limited to a maximum of 10 where not already limited to a lower value by other design requirements. This amplification factor is defined as the total displacement of any point on the item under test divided by the displacement of the input device. This criteria shall be substantiated during development testing. In cases where this requirement appears difficult to accomplish, Grumman shall be consulted for direction before proceeding with the design development.

3.3.1.1.2 Vibration Design Environment. - The applied vibrational environment for the launch and boost, space flight, and lunar excursion phases of the mission consists of random excitation up to 2000 cps. The high acceleration density levels at low frequencies are presented in Table II for use in design analysis only, since available test equipment is incapable of reproducing the complete spectrum. The test requirements include separate sinusoidal vibrations to account for this low frequency portion of the random spectrum as well as to determine the design adequacy in individual vibration modes. See test requirements in 4.4.2.2.1 and Tables VI and VII for test procedures and times. Test requirements shall be considered as part of the vibration design.

3.3.1.2 Dry Weight. -

(a) The vendor shall endeavor to produce the lightest practical Propellant System and Thrust Chamber Assemblies capable of meeting the requirements of this specification.

(b) The specification maximum dry weight shall be as shown in Table IX.

(c) The vendor shall establish and maintain a weight control program as outlined in the purchase order to insure that the maximum weight is not exceeded.

3.3.1.3 Moment of Inertia and Center of Gravity. - The vendor shall determine the center of gravity location and moments of inertia of all components and assemblies.

3.3.1.4 Configuration. - The configuration of the PS/TCA shall consist of the following:

LSC310-116	Cluster Assembly, Thrust Chamber
LSC310-121	Propellant Pressure Transducer (Cluster Inlet)
LSC310-122	Propellant Temperature Transducer (Cluster Inlet)
LSC310-125	Propellant Filter (Cluster Inlet)

3.3.1.5 Contamination. - Except for the Thrust Chamber Cluster Assembly (LSC310-116), the PS/TCA (defined in paragraph 3.3.1.4) shall be designed to operate and meet the cleanliness requirements of Grumman Specification LSP-310-0001. The propellant passages of the Thrust Chamber Cluster Assembly shall meet the cleanliness requirements of NAA Specification MC 901-0004.

3.3.1.6 Filtration. - Filtration requirements for the cluster assembly shall be in accordance with NAA Specification MC 901-0004.

3.3.1.7 Interchangeability. - The following components shall be designed for physical and functional interchangeability (in accordance with the definition of Section 6).

(a) Instrumentation and filters as specified in 3.3.2.2.

NOTE: If above components are connected by a brazing technique they are defined as replaceable in accordance with the definition of section 6.

3.3.2 Components. -

3.3.2.1 Thrust Chamber Assemblies. - The thrust chamber assemblies shall meet the requirements of NAA Specification MC 901-0004.

3.3.2.2 Propellant Control Components. - The propellant control components types shall be as follows:

(a) Propellant inlet filters.

(b) Instrumentation as required in 3.3.4.

3.3.2.2.1 Pressure. - Each pressurized component shall be capable of withstanding the proof pressure without yielding or leaking and shall withstand the ultimate pressure without structural failure.

(a) Proof Pressure 2.00 times the MEOP.

(b) Ultimate Pressure 3.00 times the MEOP.

3.3.2.2.2 Propellant Lines. - All propellant lines external to component packages will be furnished by Grumman. Flow characteristics of these lines will be provided by Grumman based on criteria established by the vendor. Conditions required at the cluster are to be mutually defined by the vendor and Grumman.

3.3.3 Electrical. -

3.3.3.1 Thrust Chamber Assembly Electrical. - The voltage power and electrical characteristics shall be in accordance with NAA Specification MC 901-0004.

3.3.3.2 Power Requirements. - A power utilization analysis shall be performed by the vendor. This analysis shall take into consideration power consumption, reliability, weight, design, performance and electromagnetic interference. The analysis along with completed Form LSK-390-1027 shall be submitted to Grumman for approval. When approved the power requirements shall become a part of this specification. Data shall be submitted in accordance with the Purchase Order.

3.3.3.3 Electrical Circuit Design. - Instrumentation shall meet the performance and design requirements of this specification as listed below. Thrust chamber assembly circuit design shall be in accordance with NAA Specification MC 901-0004.

(a) Electrical bonding shall be provided in accordance with MIL-B-5087.

(b) An electrical return wire shall be utilized in all electrical components forming part of the PS/TCA.

(c) All electrical elements shall be electrically isolated from their housings.

3.3.3.3.1 Electromagnetic Interference. - Instrumentation shall be designed to operate and meet the electromagnetic interference requirement of Grumman Specification LSP-530-001.

3.3.3.3.2 Electrical Component Design. - Instrumentation shall be designed for the service and the environmental conditions in 3.5 and Table II of this specification.

3.3.3.3.3 Dielectric Strength. - Instrumentation shall withstand without electrical breakdown a dielectric voltage in accordance with MIL-STD-202, Method 301, except that the details shall be specified in the individual component specification.

3.3.3.3.4 Insulation Resistance. - Instrumentation shall maintain a minimum isolation resistance in accordance with MIL-STD-202, Method 302, the details of which shall be specified in the individual component specification.

3.3.3.3.5 Ignition Proof. - Instrumentation or operation of same shall not ignite any explosive mixture surrounding the PS/TCA (i.e., hydrogen and oxygen).

3.3.3.3.6 Fail-Safe Provisions. - Failure of PS/TCA instrumentation shall not propagate sequentially. Design shall fail safe.

3.3.3.3.7 Electrical Drawing Symbols. - Electrical drawings shall be made in accordance with Section 15 of the MSFC Drafting Manual.

3.3.3.4 Electrical Wiring. - The installation of wiring and wiring devices used for the electrical components in the PS/TCA shall meet the functional and environmental requirements as set forth by this specification.

3.3.3.4.1 Wiring Internal to PS/TCA Units (Clusters and Components). - Internal wiring shall be installed to:

(a) Provide accessibility for inspection and maintenance.

(b) Minimize the possibility of damage.

(c) Prevent chafing and provide protection when wires or cables are routed.

(d) Provide separation of wires or cables from lines containing propellants.

(e) Minimize the radius of bend to a value that shall be subject to approval by the Grumman Resident Quality Control Representative.

(f) Minimize excessive slack.

(g) Effectively eliminate electromagnetic interference to the limits specified in Specification LSP-530-001.

(h) Secure wires and cables when routed through structural members.

(i) Prevent mechanical strain that would tend to break the conductors and/or the connections.

(j) Wires and cables shall be supported at suitable intervals to prevent excessive movement under all vibration conditions.

3.3.3.5 Electrical Connections. - Wiring from each component shall pigtail from the component.

3.3.3.5.1 Component Connection. - Electrical connections within each component shall be welded, brazed or soldered. Soldering shall be in accordance with MSFC-PROC-158 and MSC-ASPO-S-5, except that all references to MSFC and MSC shall be interpreted to be Grumman.

3.3.3.5.2 PS/TCA Components and Cluster Wire Connections. -

3.3.3.5.3 Thrust Chamber Cluster Assembly. - Wires from the TCA's contained within this cluster shall be pigtailed. Length of instrumentation pigtails shall be six (6) ft. minimum.

3.3.3.6 Wires and Cables. - The wire and cable used shall be suitable for continuous operation at 600 volts rms maximum at the environments specified in Table II.

3.3.3.7 Thermal Design. - A prime consideration in the design of all electrical and electrically operated devices shall be the thermal effect of a space vacuum on rated and overload characteristics of electrical devices. The vendor shall conduct an analysis of these characteristics.

3.3.4 Instrumentation. - Provision shall be incorporated to monitor the performance of the equipment during all phases of its testing and operation.

3.3.4.1 Excitation Voltage. - The following excitation voltages will be supplied by Grumman:

(a) 28 VDC unregulated.

3.3.4.2 Inaccessible Areas. - As a design objective, location of sensors in inaccessible areas is to be avoided.

3.3.4.3 R & D (Flight Test) Measurements. - Additional pick-up points shall be required for R & D (Flight Test) Instrumentation to be specified by Grumman.

3.3.4.4 Measurements. - The following instrumentation consisting of the pickup point and the transducers shall be provided by the vendor.

Measurement Parameter	Expected Range	Quantity	Response
Chamber Pressure	0-125 psia	16	600 cps
Injector Housing Temperature	0°F to $+500^{\circ}$F	16	Steady State
TCA Pair/Fuel Inlet Pressure	0-500 psia	8	330 cps
TCA Pair/Fuel Temperature	-75°F to $+200^{\circ}$F	8	Steady State
TCA Pair/Oxidizer Inlet Pressure	0-500 psia	8	330 cps
TCA Pair/Oxidizer Temperature	-75°F to $+200^{\circ}$F	8	Steady State

3.3.4.4.1 Transducers. - All transducers shall be selected from the Grumman instrumentation selection list (LLI-360-1) or as approved by Grumman. The transducers selected for each application shall have an inherent reliability such that they shall not cause any functional failure of the equipment, and shall be compensated such that their capability to perform the intended function is not degraded by the environmental conditions to which they are subjected.

3.3.4.4.2 Calibration. - Vendor shall calibrate all transducers at reasonable intervals with equipment traceable to the National Bureau of Standards. Calibration procedures and equipment approved by Grumman shall be used.

3.3.5 Control. - Thrust control shall be as specified in NAA Specification MC901-0004.

3.4 Propellants and Fluids. -

3.4.1 Propellants. -

3.4.1.1 Fuel. - The fuel shall be a mixture of 50% hyrazine (N_2H_4) and 50% unsymmetrical dimethylhydrazine (UDMH) conforming to MIL-P-27402.

3.4.1.2 Oxidizer. - The oxidizer shall be nitrogen tetroxide (N_2O_4) conforming to MIL-P-26539.

3.4.2 Mixture Ratio. - The oxidizer to fuel mixture ratio by weight shall be as specified in NAA Specification MC901-0004.

3.4.3 Temperature. - Propellant temperature shall be as specified in Table II.

3.4.4 Pressure. - The PS/TCA shall be designed to operate with propellants pressurized to the following characteristics:

(a) 181 $\pm$ 4 psia regulated pressure.

(b) 191 psia (maximum) at regulator lock-out.

(c) 250 psia (maximum) at relief setting operation.

3.4.5 Leakage. - Internal leakage of the system fluids under operating and non-operating pressures which would impair or endanger system operation shall not be permitted. External leakage of propellants shall not be permitted under operating and non-operating pressures either during ground checkout or operation. Leakage across thrust chamber valve poppet seal shall be in accordance with the requirements of NAA Specification MC901-0004.

3.4.6 Lubricants. - There shall be no lubricants used.

3.4.7 Propellant Drains. - The components shall be designed to minimize fluid entrapment for any installed attitude. The component shall provide for fluid removal by dry gas and/or liquid purging.

3.5 Environmental and Load Factors. - The Propellant System and Thrust Chamber Assemblies shall be required to meet all the requirements of this specification during and after exposure to the combined environment specified in Table II or Table III as applicable.

3.5.1 Radiation Environment. - Charged particle and electromagnetic radiation originating from the sun and other celestial sources, shall be considered in the design of the PS/TCA. The vendor shall notify Grumman of any items which may be adversely affected.

3.6 Fabrication. -

3.6.1 Materials. - In the selection of materials and processes, fulfillment of major design requirements shall be the prime consideration. Materials selected shall be subject to Grumman review.

3.6.1.1 Dissimilar Metals. - Dissimilar metals shall not be used in intimate contact unless suitably protected against electrolytic corrosion. When it is necessary to assemble any combination of dissimilar metals, an approved interposing material compatible to each as well as the environment shall be used. Some of the more commonly used dissimilar metals are defined in the following groups.

GROUPING OF METALS

Group I	Magnesium and its alloys Aluminum alloys 5052, 5356, 6061 and 6063.
Group II	Aluminum and its alloys including aluminum alloys listed in Group I.
Group III	Iron, Leak and Tin and their alloys (except stainless steel)
Group IV	Copper, chronium, nickel, (inconel), silver, gold, platinum, titanium, cobalt and rhodium and their alloys; stainless steels and graphite.

(a) Contact between a member of any one group and another member of the same group shall be considered as similar. Contact between a member of one group and a member of any other group shall be considered as dissimilar.

3.6.1.1 (Continued)

Group IV (Continued)

(b) Unless specifically approved by Grumman, all other metals shall be considered dissimilar with respect to each other and with respect to any of the materials listed above.

(c) The above grouping is intended to serve as a guide in selecting materials, and shall not be construed to waive other requirements of this specification pertaining to corrosion resistance of components and assemblies.

(d) Where reference is made to a metal in a particular group, the reference applies to the metal on the surface of the part; i.e., gold means gold wire, as well as gold electroplate.

(e) Different metals in contact, even though similar, shall be employed in assemblies in such manner than the smaller part is cathodic or protected and the larger part is anodic.

(f) Qualified standard parts and attaching hardware, which are cadium, silver or nickel plated, etc., may be used without additional protection provided the finish thereon, is acceptable to Grumman, and adequate protection against corrosion is afforded.

3.6.1.1.1 Protection Against Electrolytic Corrosion. - Where it is necessary that any combination of dissimilar metals be assembled, the following methods or combinations of methods shall be emploued for the alleviation of electrolytic corrosion, unless other design considerations preclude the employment of such methods.

(a) Interposition of a material compatible to each to decrease electrolytic potential differences, such as nickel or silver plate on steel in contact with inconel.

(b) Interposition of an inert material between the dissimilar metals to act as a mechanical and insulating barrier.

3.6.1.1.1 (Continued)

(c) Design of dissimilar metal or similar metal contacts, in order that the area of the cathodic metal is relatively smaller than the area of the anodic metal, such as screws, of stainless steel or nickel plated brass in the contact with aluminum.

3.6.2 Processes. - All processes, processing equipment and certification or processing personnel shall be subject to Grumman approval.

3.6.2.1 Quality. - When non-governmental specifications are used for processes which may affect performance, reliability or durability of the PS/TCA such specifications shall be approved by Grumman. The use of non-governmental specifications shall not constitute waiver of inspection.

3.6.2.2 Workmanship. - The workmanship and finish shall be of sufficiently high grade to insure satisfactory operation, reliability and durability consistent with the service life and application of the PS/TCA.

3.6.3 Standards. -

3.6.3.1 Parts. - AN, MS, JAN, or MIL standard parts shall be used wherever they are suitable for the purpose, and shall be identified by their standard part numbers. The use of non-standard parts will be approved by Grumman only when standard parts have been determined to be unsuitable.

3.6.3.2 Design. - MS and AND design standards shall be used wherever applicable.

3.6.3.3 Joints. - Particular attention shall be paid to the development of high reliability, leak proof methods of joining the fluid system lines to the PS/TCA components. Installation configuration restraints affecting the method of joining will be defined by Grumman. Final configuration of the line attachment provisions on each of the PS/TCA components is subject to Grumman approval.

3.6.4 Special Tools. - The design of the PS/TCA shall minimize the need for special tools for maintenance and servicing of the PS/TCA. When special tools are required, their need shall be subject to Grumman approval.

3.7 Identification of Product. -

3.7.1 Assemblies. - Permanent serialization of all major components shall be accomplished during manufacture. Identification of components shall be accomplished with nameplates or other suitable means. In cases where nameplates are employed, the following information shall be represented in accordance with MIL-STD-130:

Item Name

Prime Contractor Specification Control Drawing No.

Stock No.

Contract No.

Inspection Serial No.

Manufacturer's Part No.

Manufacturer's Name

Manufacturer'r Serial No.

Assembly Date

U.S.

3.7.2 Components. - Components shall be clearly marked as follows:

Serial No.

Stock No.

Manufacturer's Part No.

Manufacturer's Name

3.8 Reliability Requirements. -

3.8.1 Numerical Reliability. - The probability of successful operation of one thrust chamber assembly shall be as specified in NAA Specification MC 901-0004 for completion of the performance requirements as detailed in Para. 3.2. The probability of successful operation of one cluster mount assembly and associated instrumentation and filters shall be .999999 for completion of the performance requirements as detailed in Para. 3.2.

3.8.2 Safety. - The probability of safety goal shall be .999999 for completion of the mission without catastrophic failures such as engine explosion or propellant leakage causing damage to other subsystems.

3.8.3 Operational Profile. - The reliability requirements of 3.8.1 and 3.8.2 shall be based on the mission profile in Table IV and environmental conditions of Table II or Table III as applicable.'

4 QUALITY ASSURANCE PROVISIONS

4.1 General. - This section of the specification establishes general test requirements and procedures to be followed during the Propellant System and Thrust Chamber Assemblies (PS/TCA) test program. The vendor may propose additional tests to further increase the effectiveness of this program. Changes to specific tests and test conditions will evolve and be approved by Grumman based upon future vendor and Grumman study and development efforts. The test program shall consist of the following test categories:

(a) Development Tests

(b) Component Qualification Tests

(c) System Design Verification Tests

(d) Acceptance Tests

4.1.1 Witnessing of Tests. - Grumman's resident Engineer shall be provided with all test schedules for this program so that a representative may be designated to witness the tests.

4.1.2 Criteria for Rejection. - Criteria for rejection of a test specimen shall be stated in the acceptance test specification. In general, any degradation in performance beyond specified limits shall be cause for rejection.

4.2 Test Facilities. - Private, commercial or government test facilities may be used subject to Grumman approval.

4.2.1 Environmental Test Facilities. - The environmental test facility or chamber shall be of a sufficient size and volume such that the item under test shall not interfere with the generation and maintenance of the required test condition.

4.2.2 Standard Conditions. - Tests conducted without utilizing special environments shall be conducted under the following conditions:

(a) Temperature local ambient

(b) Relative Humidity: Local atmospheric

(c) Barometric Pressure: Local atmospheric

4.2.3 Instrumentation Calibration. - All inspection measuring and test equipment shall be calibrated against certified secondary standards, which have been calibrated against primary standards by the National Bureau of Standards or an accepted testing organization. The calibration intervals shall be proposed by the vendor and be subject to approval by Grumman. Records shall be maintained indicating the date of last calibration and due date. The due date shall be displayed on each item of inspection, measuring, and test equipment or tools. The procedures and means shall be provided for periodic operational checks on each item of inspection, measuring, and test equipment prior to use (e.g., warmup and setting of electronic instruments, and check of micrometers against shop standards).

4.2.3.1 Tolerances. -

(a) Test Equipment - All measurements of test conditions shall be made with instruments having an accuracy of at least one fifth the tolerance for the variable to be measured. Deviations from this requirement shall have approval by Grumman.

(b) Test Conditions - The maximum allowable tolerances of test conditions (exclusive of accuracy of instruments) shall be specified for each test. Acceptable values are:

(1) Temperature: $\pm$ 3.6°F

(2) Sinusoidal Vibration Amplitude: $\pm$ 10%

(3) Sinusoidal Vibration Frequency: $\pm$ 2%

(4) Random Vibration: The vibration acceleration density applied to the test item shall be within $\pm$ 3 db of the specified test level over broad regions of the spectrum between 20 and 1000 cps and $\pm$ 4 db between 1000 and 2000 cps.

(5) Shock Amplitude: $\pm$ 15%

(6) Acceleration $\pm$ 10%

(7) Pressure:

Barometric	$\pm$ 5%
Gauge	$\pm$ 5%
Vacuum	a - cell 9 pad D $\pm$ 5% b - other: less than 1×10^{-5} mm Hg

(8) Relative Humidity: $\pm$ 5%

(9) Time: $\pm$ 5%

4.2.3.1 (Continued)

(b) (Continued)

(10) Simulated Thermal Radiation: Incident thermal radiation (0.3 to 2.0 microns) shall be simulated with sufficient precision so that the energy absorbed by the receiving body is with ± 5% of the energy expected to be absorbed from the applicable celestial body or other source. The vendor shall verify the calibration, collimation, uniformity of field and spectral distribution of all simulators to the satisfaction of Grumman.

(11) Black Space: Space shall be simulated by chamber cold walls at liquid nitrogen temperature or colder. The emittance of the chamber walls shall be at least 0.90 over the infrared portion of the electromagnetic spectrum. Chamber windows, uncooled doors, etc., shall not appear in the field of view of the equipment due to the large thermal effects which result.

(12) Power: As required.

(13) Weight: ± 1/2 percent

4.2.4 Mounting Adapters. - The mounting adapters shall expose the items under test to the test environment in a manner that is representative of that in which it will be exposed in the LEM System.

4.3 Test Procedures. -

4.3.1 Shock. - The shock test shall be conducted in accordance with MIL-STD-810, Method 516, Procedure I, modified to a sawtooth shock pulse with a linear rise time of 11 ± 1 millisecond and a 1 ± 1 millisecond decay time. The measurement of the shock input shall be accomplished at the mounting interface of the test unit. The test shall be conducted under standard conditions of 4.2.2.

4.3.2 Vibration. - The test units shall be attached to a mounting adapter in a manner identical with the actual mounting of the test unit in the spacecraft. The vibration shall be accomplished in the three mutually perpendicular directions parallel to the spacecraft x-x, y-y and z-z coordinate axes, defined in Figure 3. Unless the equipment under test is mounted directly to primary structure, specified vibration inputs shall be applied and monitored at the attachment of secondary structure to primary structure. Grumman will supply the vendor either design information for use in fabricating supports, or the actual supporting secondary structure. Slip tables may be utilized where other test input methods are not practical.

A complete log of each vibration test shall be maintained, including all resonant frequencies, instrumentation used, design changes made, and a detailed account of the performance of the equipment under test. In attempting to equalize the vibration input or in the determination of specimen or fixture resonances, it may be necessary to apply some vibration energy to the test unit prior to actual test. In such cases the rms-g value shall be kept to a minimum and in any event shall not exceed 50% of that required during the actual test. All vibration tests will be conducted under both high and low temperature while undergoing the vibration requirements.

4.3.2.1 Vibration Fixtures. - The fixtures holding the test specimen on the shaker head shall be capable of transmitting the vibrations specified herein. It shall be a design objective that these fixtures are free of resonances within the test frequencies. In any event, resonant frequencies of fixtures compensated for test specimen mass shall be above 750 cps. The transverse motion (crosstalk) in any direction produced by these fixtures shall not exceed the vibration levels specified herein. The requirements outlined above shall be verified by a sinusoidal vibration test sweep using a dummy specimen of proper mass. The vibration input shall be monitored with tri-axial accelerometers.

4.3.2.2 Sinusoidal Vibration. - The vibration input levels shall be measured at or near each test unit mounting location. Wherever more than four mounting locations exist, only four points need be monitored. Any accelerometer fastened at one of the mounting locations can be used as the servo control input provided that:

4.3.2.2 (Continued)

(a) The control input maintains levels at the test frequency within $\pm$ 1 db of the requirements.

(b) The level at any input location is within $\pm$ 4 db of the requirements at all frequencies.

(c) The average of all inputs at each test frequency is within $\pm$ 2 db of the requirements.

Exceeding the lower limits of the above tolerances will be cause for rejection of the delinquent portion of the test and will necessitate rerunning of that part of the vibration test. The recording of the accelerometer output signals shall be accomplished on a continuous recording device, e.g., magnetic tape, oscillograph, etc. The recorder shall have sufficient response capability such that the complete wave form of the signal may be examined and analyzed.

4.3.2.3 Random Vibration. - The vibration input shall be controlled from the same accelerometer as used to control sinusoidal vibration tests. The spectrum at test levels shall be analyzed and a plot of acceleration spectral density (g^2/cps) versus frequency shall be compiled for each random test. The analyzing filter shall have a maximum bandwidth of 1/3 octave or 100 cps, whichever is less.

4.3.2.4 Resonance Search. - A sinusoidal resonance search shall be conducted at half or less of the required sinusoidal qualification test levels before any portion of the vibration test is conducted. Resonant frequencies and vibration amplifications shall be noted in the test log. The vibration amplification of any portion of the equipment shall be in accordance with 3.3.1.1.1.

4.3.3 Sustained Acceleration. - The test unit shall be mounted on the test apparatus (centrifuge) in such positions as to produce the required accelerations. The test apparatus shall be of such size that the gradient across the test item shall not be greater than $\pm$ 15 percent of the input acceleration through the c.g. of the test item. The test shall be run at standard conditions.

4.3.4 Proof Pressure. - (Proof pressure test shall be conducted on all components which contain fluid pressure.) Proof pressure shall be imposed on the vessel and held for at least 2 minutes. Evidence of deformation adversely affecting operation or permanent set shall be cause for rejection.

4.3.5 Burst Pressure. - (Burst test shall be conducted on all components which contain pressure.) The minimum bursting pressure shall be 1.50 times the proof pressure. The rate of application shall be in increments equal to 10 percent of the burst pressure until proof pressure is reached, then in increments of 5 percent burst pressure for a period of 15 seconds minimum. During these tests, the pressure causing initial yield of the material shall be determined where practicable and the burst pressure recorded, together with a description of the nature of the failure.

4.3.6 Thermal Vacuum. - The test item shall be placed in a vacuum chamber and subjected to the pressure specified. The vacuum shall be maintained for the total period of the test. While under vacuum, the item shall be subjected to the high and low temperature conditions of the test. The temperature shall be maintained and monitored on the heat sink surface of the specimen at the values specified. All sides of the test item including the heat sink interface and any insulation shall simulate the actual installation so that the heat transfer environment is reasonably duplicated. The thermal dissipation of the equipment at test temperature shall be measured. Unless otherwise specified, the test item shall be continuously operated during the test and its performance monitored. Temperature probes shall be located internally in the equipment and externally to demonstrate that the thermal gradients and component temperatures are acceptable.

NOTE: The limits of the test facility will govern thermal vacuum testing for the clusters.

4.4 Classification of Tests. -

4.4.1 Development Tests. - Development tests are those tests conducted for the purpose of providing data for use in the design or to support the design of a specific component, section or subsystem.

4.4.1 (Continued)

Development tests may be used to determine operating characteristics under off-design conditions. Test-to-failure type development tests can provide failure mode and weak line characteristics for verification of analyses and determination of strength margins. The vendor shall prepare a development test plan summary for review by Grumman. Development tests shall include:

(a) Component Development Tests

(b) System Development Tests

4.4.1.1 Component Development Tests. - Component development tests shall include all tests conducted for the purpose of component and subassembly design and material selection, and for the investigation of component and subassembly performance characteristics.

During system development testing, procedures for cleaning and flushing the system and techniques for propellant loading shall be evaluated. There shall be a minimum of two development system configurations.

(a) Configuration number one shall consist of a standard vendor supplied pressurization system utilizing either nitrogen or helium as the gas pressurant and vendor supplied development hardware for the propellant feed system and thrust chamber assemblies.

(b) Configuration number two shall consist of advanced stage vendor development components for the purpose of conducting system integration tests with GAEC supplied Helium Pressurization System (HPS) and propellant tanks.

4.4.1.2 System Development Test. - During system development testing, procedures for cleaning and flushing the system and techniques for propellant loading shall be evaluated. There shall be a minimum of two development system configurations.

(a) Configuration number one shall consist of a standard vendor supplied pressurization system utilizing either nitrogen or helium as the gas pressurant and vendor supplied development hardware for the propellant feed system and thrust chamber assemblies.

4.4.1.2 (Continued)

(b) Configuration number two shall consist of advanced stage vendor development components for the purpose of conducting system integration tests with Grumman supplied Helium Pressurization System (HPS) and propellant tanks.

4.4.2 <u>Component Qualification Tests</u>. -

4.4.2.1 <u>General</u>. - Qualification tests are tests which are conducted on samples identical to production PS/TCA components. These tests shall be conducted on a single specimen for each component. Prior to the start of the qualification test program each test unit shall undergo acceptance tests in accordance with 4.4.4 of this specification. All PS/TCA components requiring qualification, inspection, and testing as specified herein may have these requirements waived at the option of Grumman if the component has been previously qualified at the same or higher level for service use on another vehicle. These components must be substantially identical to the respective components previously qualified. If such a waiver is granted, detailed information on the components for which previous approval was obtained shall be provided. The vendor shall prepare a separate Qualification Detail Test plan for each component and submit it to Grumman for approval prior to the start of Qualification Tests. Qualification Tests will be conducted on the filter only. Fuel and oxidizer components, that are identical with the exception of special compatibility provisions, may receive a combined qualification test subject to Grumman approval.

4.4.2.1.1 <u>Component Inspection Before Tests</u>. - All PS/TCA components shall be completely inspected for compliance with the approved drawings and specifications before qualification testing is begun. Defective parts shall not be used on any PS/TCA component subjected to qualification tests unless drawing or specification deviations have been approved by Grumman Engineering.

4.4.2.1.2 Component Inspection After Tests. - Upon completion of the Qualification Test the component shall be subjected to a detailed inspection of all vital working parts, the extent of disassembly shall be determined by Grumman inspectors. If any part is found to be defective an inspection report shall be submitted to Grumman.

4.4.2.2 Tests. - The procedure for each environmental exposure for all tests shall be as follows:

(a) Pre-exposure examination and operational test as required.

(b) Exposure to environment and operational test as required.

(c) Post-exposure examination and operational test as required.

4.4.2.2.1 Environment. - The propellant inlet filter shall be subjected to the tests listed below and the conditions of Table VII.

(a) Vibration, using the procedure of para. 4.3.2.

(b) Shock, using the procedure of para. 4.3.1.

(c) Acceleration.

4.4.2.2.2 Fluid Compatibility. - The effects on components of the chemical action of the propellants within the specification temperature limits of the propellants as well as the effects of aging with propellants drying in air, contact with vapors, or the worst combination thereof, shall be determined, and acceptance criteria shall be proposed in the test plan. The test conditions shall simulate as closely as practicable those encountered in the actual application. This test shall include aging of each component with the fluid with which it is to be used, for a period of approximately (44) days, and the last seven days under pressure which the component will be subjected to a normal mission operation.

4.4.2.2.3 Static Leakage. - All components shall be tested for static leakage starting at zero differential pressure and increasing at a rate consistent with normal use to the MEOP.

4.4.2.2.4 Proof Pressure. - All components shall be tested at the proof pressure specified in Section 3 and in accordance with the procedure of 4.3.4.

4.4.2.2.5 Burst Pressure. - All components which contain pressure shall be subject to the burst pressure in accordance with 4.3.5.

4.4.2.2.6 Electrical Tests. - All electrical components shall be tested according to MIL-STD-202, Methods 301 and 302.

4.4.2.2.7 Functional. - A functional test shall consist of the specified number of cycles of operation of the component. Sufficient measurements shall be made over the entire test period to compare the most significant dynamic and static control functions for each environmental condition under which the test is conducted. Performance throughout the various functional tests shall be within the limits specified.

4.4.2.2.8 Calibration. - Sufficient dynamic and static measurement data shall be obtained to empirically define the functions of the components within the normal operating range including discontinuties, hysteresis, and dead bands. The recalibration values determined during testing shall remain within the performance limits specified.

4.4.2.2.9 Weight. - All PS/TCA components shall be weighed dry.

4.4.3 Design Verification Tests. -

4.4.3.1 General. - Design verification tests are advanced stage development tests which are performed to demonstrate the proper performance and operating characteristics of the production design. Design verification hot firing tests will be conducted on complete PS/TCS's at sea level, and on thrust chamber assembly clusters under simulated altitude conditions.

4.4.3.1.1 Selection of Test Limits. - Unless otherwise specified for a particular test, the test limits for the design verification tests shall be as shown in Table VI.

4.4.3.1.2 Parts Failure and Replacement. - Maintenance, adjustment, or replacement of parts shall not be permitted, during design verification testing except as defined in the design verification test plan. Other changes to the system shall be as mutually agreed upon within an 8 hour period after a request has been made by the vendor.

4.4.3.1.3 Inspection After Tests. - After completion of tests, calibrations shall be made of all controls and control components prior to disassembly. These calibrations shall demonstrate that the components are within the design tolerance range required. The test articles shall then be completely disassembled. Visual examination and measurements of all parts shall be made. Where practicable, photographs shall be taken of all excessively worn, distorted or weakened parts.

4.4.3.1.4 Design Verification Conditions. - Verification of the PS/TCA and cluster designs shall be predicated on maintenance of all parameters within the limits specified.

4.4.3.2 PS/TCA Design Verification. -

4.4.3.2.1 General. - System design verification tests are conducted on a complete PS/TCS with fully loaded and temperature conditioned propellant tanks and with a Grumman supplied helium pressurization system. The system shall be installed on a test stand fabricated to comply with Grumman definitions of LEM location points. Each component shall be of qualification design, but within this constraint, previously used development and qualification test hardware may be employed where practical.

4.4.3.2.2 Data Requirements. - The test system shall be instrumented to provide a continuous record of the following values:

(a) Propellant feed pressures to each thrust chamber assembly pair.

(b) Chamber pressure.

4.4.3.2.2 (Continued)

(c) Oxidizer and fuel tank pressures.

(d) Primary pressure-regulator discharge pressure.

(e) Gas pressurization source pressure and temperature.

(f) Current/voltage for each thrust chamber valve.

(g) Thrust chamber injector and propellant temperatures.

(h) Barometric pressure.

(i) Other, as agreeable to Grumman and the vendor.

NOTE: Thrust values will be measured indirectly with the thrust coefficient characteristics determined from individual thrust chamber assembly tests.

Using the above measured values, the vendor shall derive the thrust coefficient characteristics determined from individual thrust chamber assembly tests.

4.4.3.2.2.1 Pulse Mode. - The following characteristics shall be derived for the first five pulses, the middle pulse and the final pulse of each thrust chamber assembly firing series.

(a) Total impulse per pulse.

(b) Average chamber pressure per pulse.

(c) Average thrust per pulse.

(d) Other, as required to demonstrate performance.

4.4.3.2.2.1 (Continued)

The following characteristics shall be derived from a compilation of the first, middle, and final pulses of all applicable thrust chamber assembly test series employed in PS/TCA verification testing.

(a) Total impulse per pulse vs. pulse width and off-time.

(b) Average chamber pressure per pulse vs. pulse width.

(c) Average thrust per pulse vs. pulse width.

(d) Thrust pulse width vs. electrical pulse width and hardware temperature.

(e) Maximum soak-back temperature vs. pulse width and off-time.

(f) Other, as required to demonstrate performance.

4.4.3.2.2.2 <u>Steady State Mode</u>. - The following operational characteristics based on the first point, mid point, and final point of each thrust chamber steady state run shall be derived:

(a) Total impulse of run.

(b) Thrust

(c) Other, as required to demonstrate performance.

The following operational characteristics shall be derived from a compilation of all applicable mid-points of each thrust chamber steady state run employed in PS/TCA verification testing.

(a) Deviation from design nominal of chamber pressure and thrust vs. oxidizer and fuel temperature.

(b) Other, as required to demonstrate operational characteristics.

4.4.3.2.3 PS/TCA Tests. - The PS/TCA shall be subjected to the below listed tests which are detailed in the succeeding paragraphs of this specification. The number of systems employed and order of tests shall be specified in the detailed test plan. The detailed test plan shall define the use of the power and emergency coils of the thrust chamber solenoid valves to demonstrate operational and life characteristics of each coil. The vendor shall provide a detailed test plan to be approved by Grumman prior to the initiation of PS/TCA design verification testing. The formulation of this test plan shall be based upon the below listed "Ground Rules" and "Test Objectives".

4.4.3.2.3.1 Ground Rules. -

(a) Definitions -

(1) Pulse Mode Operation - Pulse width (τ) is equal to or less than one second.

(2) Steady State Operation - Pulse width (τ) is equal to or greater than one second.

(3) Percent duty cycle (% D.C.) equals pulse width x pulse frequency (cps) x 100.

(4) Engine Couples - Engine couples are engines which provide attitude control about the x, y or z axis. The following engine combinations (Ref. Figure 2) constitute "engine couples":

Function	Engine Combinations
+X Attitude Control	IVs - IIs
+X Attitude Control	IIIf - If
-X Attitude Control	IIIs - Is
-X Attitude Control	IVf - IIf

*Primary engine combinations which are used during normal mode of Reaction Control Subsystem operation.

4.4.3.2.3.1 (Continued)

(a) (4) (Continued)

Function	Engine Combinations
+Y Attitude Control	IIIu - IVd*
+Y Attitude Control	IIu - Id
-Y Attitude Control	IVu - IIId*
-Y Attitude Control	IId - Iu
+Z Attitude Control	IVu - Id*
+Z Attitude Control	IIIu - IId
-Z Attitude Control	IVd - Iu*
-Z Attitude Control	IIId - IIu

(5) Engine Pairs - Engine pairs are engines which are fed through a single (pair) cluster isolation valve. The following engine combinations (ref. Figure 1) constitute "engine pairs":

Engine Combinations

"B" Propellant System	"A" Propellant System
IVu - IVf	IVd - IVs
IIId - IIIf	IIIu - IIIs
IIu - IIs	IId - IIf
Id - Is	Iu - If

(b) Pulse Mode Operation - During pulse mode operation, engines which comprise an "engine couple" shall be operated simultaneously and in phase.

4.4.3.2.3.1 (Continued)

(c) Steady State Operation - During steady state operation, engine comprising the following combinations shall be fired simultaneously:

Engine Combinations	Function
*II - IVd	+X Translation
Id - IIId	+X Translation
IVd - IIId - IId - Id	+X Translation
*IIu - IVu	-X Translation
Iu - IIIu	-X Translation
IVu - IIIu - IIu - Iu	-X Translation
*Is - IIs	+Y Translation
*IIIs - IVs	-Y Translation
*IIf - IIIf	+Z Translation
*If - IVf	-Z Translation
IVd - IIId - IId - Id - IIs - Is	+X, +Y Combined Translation
IVd - IIId - IId - Id - IIIs - IVs	+X, +Y Combined Translation
IVd - IIId - IId - Id - IIf - IIIf	+X, +Z Combined Translation
IVd - IIId - IId - Id - If - IVf	-X, -Z Combined Translation
IVu - IIIu - IIu - Iu - Is - IIs	-X, +Y Combined Translation
IVu - IIIu - IIu - Iu - IIIs - IVs	-X, -Y Combined Translation
IVu - IIIu - IIu - Iu - IIf - IIIf	-X, +Z Combined Translation
IVu - IIIu - IIu - Iu - If - IVf	-X, -Z Combined Translation

(d) Operating Time - Minimum operating time on each engine shall be as follows:

(1) 500 seconds of accumulative steady state operation. A minimum of two engines shall be operated continuously for at least 500 seconds each.

(2) 500 seconds of accumulated ON-TIME during pulse mode operation. During this period of time, each engine shall be subjected to a minimum of 35,000 pulses.

(e) Typical pulse width (τ) and % duty cycle to be run are as follows:

4.4.3.2.3.1 (Continued)

(e) (Continued)

Pulse Mode	
τ (sec)	% D.C.
0.010	25
1.0	25
0.020	50
0.040	70
0.080	70
0.140	70
0.200	70

STEADY STATE
τ (sec)
5
15
70
500

(f) The following events shall be performed by each "engine pair":

(1) Both engines start steady state.

(2) Both engines stop steady state.

(3) One engine start steady state while other is running steady state.

(4) One engine stop steady state while other is running steady state.

(5) Both engines start pulsing under the following conditions:

a. Same frequency and in phase.

b. Same frequency and out of phase.

c. Different frequencies.

(6) Both engines stop pulsing under conditions of step 5.

(7) One engine start pulsing while other is pulsing (same pulsing conditions as specified in step 5).

4.4.3.2.3.1 (Continued)

(f) (Continued)

(8) One engine stop pulsing while other is pulsing (same pulsing conditions as specified in step 5).

(9) One engine switch to pulsing mode from steady state while other running steady state.

(10) One engine switch to steady state from pulsing mode while other running steady state.

(11) One engine switch to pulsing from steady state while other is pulsing (same pulsing conditions as specified in step 5).

(12) One engine switch to steady state from pulsing while other is pulsing (same pulsing conditions as specified in step 5).

(13) One engine start steady state while other pulsing.

(14) One engine stop steady state while other pulsing.

(15) One engine start steady state as other starts pulsing.

(16) One engine stop steady state as other stops pulsing.

(17) One engine start pulsing as other stops steady state.

(18) One engine start steady state as other stops pulsing.

(19) One engine start pulsing while other is running steady state.

(20) One engine stops pulsing while other is running steady state.

(21) One engine start steady state while other stops steady state.

(g) Nominal supply voltage to the injector valves shall be 26 VDC.

4.4.3.2.3.2 Test Objectives. -

(a) *Demonstrate satisfactory performance and operation for the following conditions:

(1) For normal mode of operation.

(2) With propellant system "A" shutdown, crossfeed valves opened, and all propellants being supplied by system "B".

*Performance within design limits shall be corrected to nominal design conditions, using Grumman approved correction calculations. Corrected performance shall be within the limits defined in this specification.

(3) With propellant system "B" shutdown, crossfeed valves opened, and all propellants being supplied by system "A".

(4) With system "A" regulator assembly failed in the wide open position, causing overpressurization, thereby requiring a transfer to the redundant system "A" regulator assembly.

(5) With propellant system "A" operating under high-feed pressure conditions (i.e. regulator lockout and relief setting operation).

(6) After relief valves in system "A" have been vented and then re-seated.

(7) Using only eight engines (i.e. either system "A" or system "B").

(8) With isolation valves to one cluster assembly closed.

(9) During a restart test after maximum heat soak back temperature has been achieved on the cluster assembly.

(10) When an oxidizer injector valve of one engine fails to open.

4.4.3.2.3.2 (Continued)

(a) (Continued)

(11) When an oxidizer injector valve of one engine fails to close.

(12) When a fuel injector valve of one engine fails to open.

(13) When a fuel injector valve of one engine fails to close.

(14) When one engine fails to shutdown on command signal.

(15) With maximum design voltage of 3.3.3.1.1 being supplied to engine injector valves.

(16) With minimum design voltage of 3.3.3.1.1 being supplied to engine injector valves.

(17) At OFF design O/F ratio (i.e. high and low).

(18) With propellant temperature at $+100\,^{+5}_{-0}\,^{\circ}F$. For this test the thrust chamber clusters shall be conditioned to the maximum temperature resulting from calculations employing Grumman supplied vehicle emissivities, view factors and time durations in the temperature-view environments specified in Table II(d).

(19) With propellant temperature at $+40\,^{+0}_{-5}\,^{\circ}F$. For this test the thrust chamber clusters shall be conditioned to the minimum temperature resulting from calculations employing Grumman supplied vehicle emissivities, view factors, and time durations in the temperature-view environments specified in Table II(d).

(20) When, with both systems operating, System "A" is run to propellant exhaustion.

4.4.3.2.3.2 (Continued)

(a) (Continued)

(21) When, with only system "A" operating, system "A" is run to oxidizer exhaustion.

(22) When, with only system "A" operating, system "A" is run to fuel exhaustion.

(23) With one engine starting with a fuel lead.

(24) With one engine starting with an oxidizer lead.

(25) With a failed fuel bladder.

(26) With a failed oxidizer bladder.

(b) Demonstrate repeatability of the minimum inpulse bit during the pulsing mode.

(c) Demonstrate adequate steady state performance.

(d) Demonstrate capability to operate for greater durations than those required by a typical mission mode.

(e) Performance of any additional tests which may be required as a result of the failure effects analysis.

(f) Performance of any additional tests which may be required by Grumman for the purpose of testing special features of the PS/TCA.

(g) Decontamination and Storage - With the PS/TCA in the normal launch attitude the liquid system shall be completely filled with propellants then drained, flushed, and decontaminated employing procedures developed by vendor for launch and field operations. The system shall then be removed and stored for a minimum of 30 days. Following storage, satisfactory performance of the system shall be demonstrated.

4.4.3.2.3.2 (Continued)

(h) Static Leakage - The PS/TCA shall be tested for static leakage starting at zero differential pressure and increasing at a rate consistent with normal use to the MEOP.

(i) Weight - Each PS/TCA shall be weighed dry.

4.4.3.3 Cluster Design Verification. - Cluster design verification tests supplement the PS/TCA tests. Cluster tests verify the design considerations attendant to the thermal effects of clustering the high area ratio nozzles. Hot firing tests will be conducted at a sufficiently low ambient pressure to:

(a) Insure fully flowing nozzles.

(b) To achieve sufficient plume expansion and negligible convection cooling to verify proper operation during space flight.

4.4.3.3.1 General. - Cluster design verification tests are conducted on an assembly consisting of a cluster mount and four thrust chamber assemblies. Each component shall be of production design, but within this constraint, previously used development and qualification test hardware may be employed. The propellant feed system need not employ bladders or prototype components, but shall provide feed pressure and transient responses which are consistent with a prototype feed system within constraints of facility to be utilized. A section of LEM vehicle skin structure shall be mounted to simulate cluster placement on the vehicle.

4.4.3.3.2 Data Requirements. - Instrumentation shall be implemented to provide a continuous record of the following values:

(a) Propellant feed pressures

(b) Chamber pressures

(c) Oxidizer and fuel flow rate to each thrust chamber pair

4.4.3.3.2 (Continued)

(d) Current/voltage to each thrust chamber valve

(e) Thrust chamber assembly (as many points as is necessary to establish representative temperatures vs. time histories)

(f) Ambient pressure

(g) LEM skin temperatures

(h) Other as required to demonstrate performance

Using the above measured values, the vendor shall compile and derive all data pertinent to correcting PS/TCA operational characteristics for the effects of the added thermal environmental induced by full nozzle flows.

4.4.3.3.3 Cluster Tests. - The vendor shall provide a detailed test plan to be approved by Grumman prior to the initiation of cluster design verification testing. Test plan shall include the amount hardware employed and the sequence of cluster tests. The tests shall include but not be limited to the following:

4.4.3.3.3.1 Correction Data. - The test plan shall include provisions for producing correction data for application to PS/TCA design verification tests. The purpose of the correction data is to compensate environment induced by fully flowing nozzles and exhaust plume.

4.4.3.3.3.2 Simulated Missions. - The mission phases of Table V shall be utilized to develop a test plan to test for the worst duty cycles imposed on a cluster during the mission. The test plan shall include but not limited in the following operational conditions (within design tolerances) during simulated mission tests:

(a) High mixture ratio

(b) High chamber pressure

(c) High temperature propellants and cluster hardware

4.4.3.3.3.3 Endurance Tests. - The test plan shall include tests to demonstrate the life requirements specified in NAA Specification MC 901-0004. Endurance test will be run at high and low temperature propellant and high-low temperature view environment.

4.4.3.3.3.4 Maximum Heat Soak-Back. - Included in the test plan shall be tests under the most adverse duty cycles to attain the highest thrust chamber valve temperatures prior to continuing steady state and pulse mode tests.

4.4.4 Acceptance Tests. - Acceptance tests are tests conducted on PS/TCA's components to show that the equipment is representative of, and the performance is equivalent to, the equipment used in design verification and qualification tests. All PS/TCA components delivered for Qualification Tests, and all PS/TCA components delivered under this purchase order shall be subjected to acceptance tests.

4.4.4.1 General. - The PS/TCA components, test apparatus and the material entering into the manufacture of articles for fulfillment of the requirements herein shall be subject to inspection by authorized Grumman inspectors. At convenient times prior to the tests and after the tests, the PS/TCA components shall be examined to determine compliance with all requirements of this specification. No thrust chamber assembly for delivery to Grumman shall have been subjected to more than 3 component acceptance test programs, or equivalent, without the prior approval of Grumman Engineering. Nor shall an item be delivered which has been subjected to environments of an intensity higher than acceptance test levels. Acceptance tested components shall not be disassembled following testing.

4.4.4.1.1 Test Facilities. - In accordance with 4.2.

4.4.4.1.2 Temperature and Altitude. - Temperature and altitude during acceptance tests shall be at sea level ambient conditions except for Thrust Chamber Assembly which shall be conducted under a simulated altitude of 0.2 psia maximum.

4.4.4.2 Test Procedures. - The acceptance test procedure for each component shall be supplied by the vendor for Grumman approval. All single thrust chamber firings are to be conducted under simulated altitude conditions.

4.4.4.3 Inspections and Tests. -

4.4.4.3.1 PS/TCA Components Inspection Before Acceptance Tests. - Each PS/TCA components shall be completely assembled in accordance with approved drawings, then visually and dimensionally inspected before commencing tests.

4.4.4.3.2 PS/TCA Component Tests. - Each PS/TCA component assembled for the inspection specified above shall be subjected to the following tests:

(a) Weight - The dry PS/TCA components shall be weighed and recorded.

(b) Static Leakage - Static leakage tests shall be made on each PS/TCA component according to the acceptance test plans.

(c) Calibration - The Thrust Chamber Assemblies shall be operated for a duration and at thrust levels sufficient to demonstrate compliance with performance ratings specified. The attitude of the TCA and the sequence of its operation shall be as specified in the test plan.

(d) Functional Tests - All components of the PS/TCA shall be functionally checked in accordance with the test plan.

(e) Proof Pressure - All PS/TCA components shall be tested at the proof pressure specified in Section 3.

(f) Vibration - The PS/TCA components shall be subjected to the random vibration tests using the procedure prepared in accordance with 4.3.2 with the levels of Table VIIB.

4.4.4.3.3 Acceptance Conditions. - Acceptance of the PS/TCA and its components shall be predicated on maintenance of all parameters within the limits specified throughout all tests.

4.4.4.3.4 PS/TCA Components Inspection After Test. - Upon completion of the acceptance tests, the PS/TCA components shall be subjected to inspection. If any part is found to be defective, an approved part shall be supplied to replace it, and a suitable penalty test shall be conducted.

4.4.4.3.5 Rejection and Retest. - Whenever there is insufficient thrust or other malfunctioning, or evidence that the PS/TCA component thereof is not meeting specification requirements, the difficulty shall be investigated and its cause corrected before the test is continued or rerun.

4.4.4.3.6 Maximum Running Time. - A PS/TCA component shall be rejected whenever the total running time accumulated during the tests specified herein, exceed the time allowed for in the acceptance test plan.

4.4.5 Cluster Overstress Tests. - The following tests form an integral part of the cluster development test program.

4.4.5.1 Passive Overstress Tests. - One cluster and a Grumman specified cluster support assembly shall be subjected to the vibration and shock test levels of Table VI. The cluster assembly shall be fired per the mission duty cycle of Table V. At the conclusion of these tests the cluster and cluster support assembly shall be subjected to a passive overstress test. The overstress test shall consist of systematically increasing the vibration levels above the levels of Table VI until failure occurs.

4.4.5.2 Firing Overstress Tests. - As a culmination to the development test program, one cluster assembly shall be subjected to firing overstress tests. Each engine shall be fired per the mission duty cycle until failure occurs or three minimum duty cycles are completed. All four engines of the cluster shall be fired until failure of each engine occurs providing each engine failure does not adversely affect safe operating conditions of the facility or subsequent operation of the remaining engines. Firing time of each engine must be accurately recorded.

4.4.5.3 Analysis of Results. - The vendor shall perform an engineering analysis of the data generated by the stress-to-failure tests including a correlation with the failure mode prediction analysis and submit the data and the analysis to Grumman.

5 PREPARATION FOR DELIVERY

5.1 General. - The subcontractor shall develop methods of preservation, packaging and packing for the equipment which will provide adequate protection against corrosion, contamination, physical damage from shock and vibration and other shipping hazards encountered during handling and transport to the contractor's facility, and during subsequent indoor storage. Packaging shall be designed to facilitate' handling, inspection and warehousing of the equipment.

5.2 Reliability. - The required high reliability of the equipment makes it mandatory that there be no degradation of reliability as a consequence of handling, transport and storage. In demonstration of this requirement, the supplier shall provide laboratory or field test data, service use data or suitable analytical data to verify the adequacy of the packaging materials and methods used.

5.3 Marking of Shipments. - Interior and exterior containers shall be durably and legibly marked such that the markings shall provide the following information:

Item Name

Contractor's Control No.

Stock No.

Contractor's Order No.

Manufacturer

Manufacturer's Serial No.

Date of Manufacture

6 NOTES

6.1 Definitions. -

6.1.1 Assembly, Thrust Chamber. - The thrust chamber assembly (TCA) is composed of the thrust chamber, nozzle, injector, propellant valves, mounting provisions, and any other directly associated parts.

6.1.2 Chamber, Combustion. - The combustion chamber is the enclosed volume between the injector face and the throat of the nozzle.

6.1.3 Conditions, Standard. - Standard conditions are the values of air temperature and pressure given in NACA Technical Report No. 218. The standard humidity, for the purpose of this specification, is zero vapor pressure at all altitudes.

6.1.4 Cutoff. - Cutoff is the time of propellant flow cessation through the thrust chamber propellant shutoff valve(s).

6.1.5 Duration. - The duration is the electrical on time of one operational cycle (seconds).

6.1.6 Impulse, Effective. - Effective impulse is the area under the thrust-time curve between the two 90-percent-of-rated thrust points.

6.1.7 Impulse, Effective Specific. - The effective specific impulse is the effective impulse divided by the total weight of propellant(s) consumed.

6.1.8 Impulse, Instantaneous Specific. - The instantaneous specific impulse (I_s) is the thrust produced, in pounds, divided by the total propellant consumption rate in pounds per second.

6.1.9 Impulse, Mean Specific. - The mean specific impulse is the total impulse divided by the total weight of propellant(s) consumed.

6.1.10 Impulse (Minimum Bit). - The smallest possible repeatable total impulse bit.

6.1.11 Impulse, Total. - The area under the thrust-time curve.

6.1.12 Interchangeable Parts. - Those parts which can be directly substituted for one another (both physically and functionally) by use of standard tools without cutting, fitting, or adjusting are interchangeable.

6.1.13 Model Classification. -

(a) Breadboard Model - This is an assembly of preliminary components to provide the feasibility of the system, or principle in rough form without regard to the eventual overall design or form of parts.

(b) Development Model - This is a model designed to meet the performance requirements of the specification and to establish technical requirements for production equipment. This model employs approved parts or their interchangeable equivalents. It may be used to demonstrate the reproducibility of the equipment.

(c) Prototype Model (Preproduction) - This is a model suitable for complete evaluation of mechanical and electrical form, design, and performance. It is of final mechanical and electrical form, employs approved parts, and is completely representative of final equipment. An equivalent of prototype is prequalification or design frozen hardware. Prototype hardware need not have been manufactured with production tooling.

(d) Production Model - This is an equipment in its final mechanical and electrical form, employs approved parts, and is completely representative of final equipment. Schedule permitting, qualification tests should be run on production model equipment.

6.1.14 Operation, Continuous. - Duration greater than one second.

6.1.15 Operation, Pulse Mode. - Duration less than one second.

6.1.16 Points, 90 Percent of Rates Thrust. - The 90 percent-of-rated thrust points are the time points on the thrust rise and decay which are at 90 percent of the nominal achieved thrust level.

6.1.17 Pressure, Chamber Design. - The maximum expected pressure in the chamber during operation.

6.1.18 Pressure, Effective Chamber. - The effective chamber pressure is the area under the chamber pressure-time curve between the two 90 percent-of-rated thrust points divided by the time interval between these points.

6.1.19 Pressure, Mean Chamber. - The mean chamber pressure is the area under the chamber pressure-time curve divided by the duration.

6.1.20 Pressure, Maximum Expected Operating. - The maximum expected operating pressure is the highest pressure that will appear in the PS/TCA. This value is determined from test observations.

6.1.21 Pressure, Proof. - At proof pressure there shall be no permanent deformation of the item or total deformation adversely affecting PS/TCA operation, or permanent set.

6.1.22 Pressure, Ultimate. - At ultimate pressure, there shall be no structural failure of the item.

6.1.23 Propellant, Referee. - A propellant incorporating the most adverse constituents of the specification propellant or which specifies propellant constituents after a 2-year storage period.

6.1.24 Ratio, Mean Mixture. - The mean mixture ratio (W_oW_f) is the total weight of oxidizer consumed divided by the total weight of fuel consumed.

6.1.25 Replaceable Parts. - Replaceable parts are those parts that meet all the requirements of interchangeable parts except that cutting or unbrazing of fittings for removal is allowed.

6.1.26 Thrust. - Thrust (F) is the reactive force of the rocket engine during operation.

6.1.27 Thrust, Effective. - The effective thrust is the effective impulse divided by the time interval between the two 90 percent-of-rated thrust points.

6.1.28 Thrust, Mean. - The mean thrust is the total impulse divided by the duration.

6.2 Symbols. - Symbols used in this specification are defined as follows:

Symbol	Quantity	Unit
A_e	Exit Area	in^2
A_t	Throat Area	in^2
A_w	Chamber inner surface area	in^2
C_F	Thrust coefficient $\frac{F}{p_c A_t}$	Nondimensional
cps	Cycles per second	
c*	Characteristic velocity	ft/sec
D.A.	Double amplitude of vibration	
F	Thrust	lb
g	Earth gravity	32.2 ft/sec^2
in	Inches	
I_s	Instantaneous specific impulse	lb/lb/sec
I_t	Total impulse	lb sec
L*	Characteristic length	in
min	Minutes	
n	Load factor	Nondimensional
p	Absolute pressure	lb/in^2
p_c	Chamber pressure, absolute	lb/in^2
r_m	Instantaneous mixture ratio, W_o/W_f	Nondimensional

6.2 (Continued)

Symbol	Quantity	Unit
T	Absolute temperature	Rankine
V_c	Combustion chamber volume	in^3
W	Weight of fluid	lbs
W_f	Weight of fuel	lb
W_o	Weight of oxidizer	lb
w	Fluid flow rate	lb/sec
w_f	Fuel flow rate	lb/sec
w_o	Oxidizer flow rate	lb/sec
η	Efficiency	percent

6.3 Subscripts. -

Symbol	Quantity
al	altitude
c	chamber
d	discharge
e	exhaust nozzle; exit
f	fuel
fr	friction
F	thrust
i	inlet

6.3 (Continued)

Symbol	Quantity
m	mixture
o	oxidizer
p	pressure
s, sp	specific
sl	standard sea level
st	static
v_p	vapor pressure
w	wall; surface
z	height

TABLE II

ENVIRONMENTAL AND LOAD DESIGN CONDITIONS

Add "The following conditions apply only to the thrust chamber cluster assemblies."

NOTES: 1. Factors of safety are not included in these levels. See paragraph 3.3.1.1.

2. All accelerations are in "earth g's". Multiply by earth weight or use 32.2 ft/sec^2 as appropriate.

3. The design requirements for environments such as rain, sand and dust contemplate that required protection will be established by the vendor.

(a) Pre-Launch - (The system will be unloaded for demonstration tests under these conditions)

Temperature	-65° to $+160^{\circ}$F
Acceleration	2.67g vertical with 1.0g lateral
Shock	
Packaged	Transportation, handling and storage in shipping container shall not produce critical design loads on the T, C, Q and shall not increase the weight of the T, C, Q.
Unpackaged	15g peak sawtooth shock pulse as specified in Table VI.

TABLE II (Continued)

(a) Pre-Launch (Continued)

Vibration	The following vibration levels are specified during transportation, handling, and storage. Vibration shall be applied along three mutually perpendicular axes applied to container' (sweep at 1/2 octave/minute).

For 100 lbs. or less

cps	g or D.A.
5-7-2	.5 in. D.A.
7.2-26	± 1.3g
26-52	.036 in. DA
52-500	± 5.0g

Rain	In accordance with MIL-STD-810, Method 506.
Salt Fog	In accordance with MIL-STD-810, Method 509.
Humidity	95% Relative Humidity including condensation in a temperature range of 0° to 160°F.
Electromagnetic Interference	Per LSP-530-001
Sand and Dust	In accordance with MIL-STD-810, except velocity shall be up to 2000 ft/min. at 70 ± 20°F.
Fungus	In accordance with MIL-STD-810, Method 508.

TABLE II (Continued)

(a) Pre-Launch (Continued)

Ozone	Exposure with 0.05 parts/million concentration
Explosion	In accordance with MIL-STD-810, Method 511
Pressure	0 to 50,000 ft. altitude atmospheric pressure corresponding to

(b) Launch and Boost

Temperature

-65° to $+160^\circ$F
$+40^\circ$ to $+100^\circ$F

Vibration

The mission environment consists of the following random spectrum applied for 17 minutes along each of the three mutually perpendicular axes, X, Y and Z.

Input to equipment supports from primary structure

5-13 cps	$.18g^2$/cps constant
13-15 cps	12 db/octave rise to
15-32 cps	$.30g^2$/cps constant
32-49 cps	12 db/octave rolloff to
49-950 cps	$.044g^2$/cps constant
950-1200 cps	12 db/octave rolloff to
1200-2000 cps	$.015g^2$/cps constant

Acoustics

Octave Band (cps)	Level (db)
9 to 18.8	142
18.8 to 37.5	141
37.5 to 75	141
75 to 150	138
150 to 300	134
300 to 600	130
600 to 1200	123
1200 to 2400	116
2400 to 4800	110
4800 to 9600	104
Overall	147

TABLE II (Continued)

(b) Launch and Boost (Continued)

Radiation	See paragraph 3.5.1.
Electromagnetic Interference	Same as pre-launch
Humidity	Same as pre-launch
Sand and Dust	
Altitude	Sea level to 1 x 10^{-10} mm. Hg.
Explosion	Same as pre-launch

Acceleration	X g	X Rad/Sec^2	Y g	Y Rad/Sec^2	Z g	Z Rad/Sec^2
Boost cond. (S-1C)	+4.7	-	$\pm$.1	-	$\pm$.1	-
Max. q condition (S-1C)	+2.1	-	$\pm$.5	-	$\pm$.5	-
Cut Off Condition (S-1C)	-2.6	-	$\pm$.1	-	$\pm$.1	-
Engine Hardover (S-II)	+2.3	-	$\pm$.63	-	-	-
Engine Hardover (S-II)	+2.3	-	-	-	$\pm$.63	-
Earth Orbit	0	0	0	0	0	0

Meteoroids — No effort until defined by Grumman.

(c) Space Flight

Temperature* — 40°F to 100°F

Solar Flux — 440 BTU/ft.^{2}hr.

Space — -460°F

$+260^\circ$F to -260°F at the LEM External Surface

TABLE II (Continued)

(c) Space Flight (Continued)

Electromagnetic Interference	Same as pre-launch
Pressure Altitude	1×10^{-14} mm Hg. uncontrolled vacuum

*Temperature due to combined exposure of solar flux and space shall be determined by Vendor.

Vibration

The mission environment consists of the following random spectrum applied for 6 minutes along each of the three mutually perpendicular axes X, Y and Z.

Input to equipment supports from primary structure.

5-47 cps	.089g^2/cps constant
47-65 cps	12 db/octave rolloff to
65-1000 cps	.024g^2/cps constant
1000-2000 cps	12 db/octave rolloff

Meteoroids	No effort until defined by Grumman
Radiation Source	See paragraph 3.5.1.
Ozone	To be determined.
Explosion	Same as pre-launch.

	x	Lateral	Pitch
Acceleration (Condition)	-.450g	.110g	.373 rad/sec^2
Shock (Condition)	-.84g	.12g	17.0 rad/sec^2

TABLE II (Continued)

(d) Lunar Excursion (including ascent and descent)

Temperature* — External solar flux 440 BTU/hr-ft^2
Lunar surface - -300°F to +250°F
Space - -460°F
Internal - +40°F to 100°F
+260°F to -260°F, LEM External Surface

Electromagnetic Interference — Same as pre-launch

Pressure Altitude — 1 x 10^{-12} mm Hg

Meteoroids — No effort until defined by Grumman

Radiation Source — See paragraph 3.5.1

Accelerations	X g	X rad/sec^2	Y g	Y rad/sec^2	Z g	Z rad/sec^2
Descent engine operating	+1.1	±.31	±.11	±.47	±.11	±.47
Ascent engine operating	+1.0	±.88	±.05	±.88	±.05	±2.0
Docking	0	0	0	0	-4.0	0

Landing (to be supplied)

Shock — 8g peak, any axis for 10 to 20 ms.

Landing
10-20 ms rise time - ramp step shock (preliminary)

Case 1	8.0		±14.0		
Case 2		±8.0			±14.0
Case 3			±14.0	±8.0	
Case 4	8.0				±14.0

*The thrust chamber temperature caused by exposure to expected combinations.

TABLE II (Continued)

(d) Lunar Excursion (Continued)

Vibration	The mission environment consists of the following random spectrum applied for 11 1/2 minutes (descent) and 8 1/2 minutes (ascent) along each of the three mutually perpendicular axes X, Y and Z.
	Input to equipment supports from primary structure
	10-28 cps — $.18g^2$/cps constant 28-37 cps — 12 db/octave rolloff to 37-1000 cps — $.059g^2$/cps constant 1000-1200 cps — 12 db/octave rolloff to 1200-2000 cps — $.031g^2$/cps constant
Ozone	No effort until defined by Grumman
Explosion	Same as pre-launch
Sand and Dust	No effort until defined by Grumman

TABLE III

ENVIRONMENTAL AND LOAD DESIGN CONDITIONS

The following conditions apply to the propellant inlet filters.

NOTES:

1. Factors of safety are not included in these levels. See 3.3.1.1.
2. All accelerations are "earth g's". Multiply by earth weight or use 32.2 ft/sec^2 as appropriate.
3. The design requirements for environments such as rain, sand and dust contemplate that required protection will be established by the vendor.

(a) Transportation, Ground Handling and Storage - The component is not expected to operate during exposure to these conditions.

Temperature: $-65^{\circ}F$ to $+160^{\circ}F$

Shock (Unpackaged): 30g peak sawtooth shock pulse 11 $\pm$ 1 ms rise time, 1 $\pm$ 1 ms decay time.

Vibration: For 100 lbs or less

cps	g or D.A.
5-7.2	0.5 in D.A.
7.2-26	$\pm$ 1.3 g
26-52	0.036 in D.A.
52-500	$\pm$ 5.0 g

Rain: 0.6 inches/hr for 12 hours in accordance with Method 506 of MIL-STD-810 (no direct impingement).

Salt Fog: In accordance with MIL-STD-810, Method 509.

TABLE III (Continued)

(a) (Continued)

Humidity:	100% relative humidity over a temperature, range of 40° - 100°F (including condensation)
Sand and Dust:	In accordance with MIL-STD-810, Method 510 except velocity shall be up to 2000 ft/min. at 70 ± 20°F.
Fungus:	In accordance with MIL-STD-810, Method 508.
Ozone:	Exposure with 0.05 parts/million concentration.
Explosion:	In accordance with MIL-STD-810, Method 511
Pressure:	0 to 50,000 ft. altitude
Electromagnetic Interference:	Per LSP-530-001

(b) Pre-Launch through Lunar Excursion - The component shall be capable of operating during and after exposure to applicable combinations of these environments.

Temperature:	-15°F to +105°F	
Vibration:	50-100 cps	12 db/octave rise to
	100-1000 cps	$0.35g^2$/cps constant
	1000-2000 cps	12 db/octave roll-off
Acceleration:	X	Lateral
	9g	9g

TABLE III (Continued)

(b) (Continued)

Humidity:	100% relative humidity over a temperature, range of 40° - $100^{\circ}F$ (including condensation)
Sand and Dust:	In accordance with MIL-STD-810, Method 510 except velocity shall be up to 2000 ft/min. at $70 \pm 20^{\circ}F$.
Pressure Altitude:	0 to 50,000 ft. altitude
Explosion:	In accordance with MIL-STD-810, Method 511
Salt Fog:	In accordance with MIL-STD-810, Method 509
Ozone:	Exposure with 0.05 parts/million concentration
Fungus:	In accordance with MIL-STD-810, Method 508
Electromagnetic Interference:	Per LSP-530-001
Rain:	0.6 inches/hr for 12 hours in accordance with Method 506 of MIL-STD-810 (no direct impingement)

TABLE IV

MISSION PROFILE FOR RELIABILITY ESTIMATES*

NOMINAL PHASE	MAIN PHASE	TOTAL TIME HOURS	NON-BOOST HOURS	BOOST HOURS
	Prelaunch	10.0	10.0	
	Earth Launch	0.197		0.197
	Earth Orbit Through Transportation	3.887	3.8	0.087
	Translunar LEM Checkout	1.0	1.0	
	Continued Translunar Trip Through Lunar Orbit Injection	61.29	61.2	0.09
	Coast in Lunar Orbit (LEM Checkout)	4.0	4.0(1.85)	
1	Total Pre-separation	80.374	80.0	0.374
2	LEM Separation to Insertion	0.248	0.248	
3	Insertion and Hohmann Transfer Orbit	0.97	0.968	0.002
4	Powered Descent from Pericynthion to Hover	0.107		0.107
5	Hover to Touchdown	0.033		0.033
	Post Landing Checkout	1.25	1.25	
	Exploration	1.083	1.083	
	Prelaunch Preparation	1.667	1.667	
6	Total Lunar Stay for Mission Success	4.00	4.00	
6A	Additional Lunar Stay for Crew Safety	20.0	20.0	
7	Powered Ascent and Injection	0.093		0.093
8	Transfer Coast	0.7	0.7	
9	Rendezvous (5 Nautical Miles to 500 Feet)	0.167	0.167	
10	Docking (500 Feet to Contact)	0.25	0.25	

TABLE IV (Continued)

NOTE: Stress Environmental Factor (=K)

Boost-Operate* = 10	Boost-Non-Operate = 0.01
Non-Boost-Operate* = 1	Non-Boost-Non-Operate = 0.001

*Operate: (a) Propellant system is considered to be in operating state whenever it is pressurized.

(b) Thrust chamber assemblies are considered to be in operating state whenever they are firing.

TABLE V - MISSION DUTY CYCLE

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[illegible]	[illegible] TIME	OPERATION	THRUSTERS	TIME OF OPERATION	COAST TIME BETWEEN FIRINGS	L.C., #PULSES/THRUSTER (AXES), P.W.
Descent						
Checkout		Fire all Jets	1 through 16	1.5 sec. ss *	-	-
Separation	1.3 min	Trans. 100 ft. in x	10, 2 9, 1	10.85 sec. ss 10.85 sec. ss	29 sec.	.1°; 2, 2, 2, (x, y, z), 10 ms
		90° Rot. about y	5, 2 1, 6	1.675 sec. ss 1.675 sec. ss	16.3 sec.	.1°; 2, 2 (x, z), 10 ms
Ullage Settling Injection into Sync. Orbit	9.2 min.	Thrust in + x 4° Rot. about y	2, 10, 6, 14 5,2 1,6	5 sec. ss .875 sec. .875 sec.	- 0	- -
		Trim Gimble (Attitude Control)	5,2,1,6; 1,14,13,2	30 sec., pulsing	-	.1°; 49, 49 (y, z), 10 ms
Coasting Descent	152 min.	5° Limit Cycle	12,4,16,8; 5,2,1,6 1,14,13,2	8660 sec. pulsing	-	5°; 6, 6, 6, (x, y, Z), 10 ms
Landmark Observation (1)		94° Rot. about y	5;2 1,6	1.675 sec. ss 1.675 sec. ss	17 sec.	.1°; 2, 2 (x, z), 10 ms
Landmark Observation 2-7		** (6) 30° Rot. about y	5,2 1,6	1.675 sec. ss 1.675 sec. ss	4.3 sec.	.1°; 2,2 (x, z), 10 ms
Lunar Day, Sun Preparation		90° Rot. about x	12,4 16,8	1.675 sec. ss 1.675 sec. ss	16.3	.1°; 2, 2 (y, z), 10 ms
		30° Rot. about y	5,2 1,6	1.675 sec. ss 1.675 sec. ss	4.3 sec.	.1°; 2, 2 (x, z), 10 ms
Up-date LEM IMU		30° Rot. about y	5,2 1,6	1.675 sec. ss 1.675 sec. ss	4.3	.1°; 2, 2 (x, z), 10 ms
Synchronous Orbit Update		91° Rot. about x	12,4 16,8	1.675 sec. ss 1.675 sec. ss	16.5 sec.	.1°; 2, 2 (y, z), 10 ms
		31° Rot. about y	5,2 1,6	1.675 sec. ss 1.675 sec. ss	4.5 sec.	.1°; 2, 2 (x, z), 10 ms
Initiate Powered Descent		26.5° Rot. about y	5,2 1,6	1.675 sec. ss 1.675 sec. ss	3.6 sec.	.1°; 2, 2 (x, z), 10 ms
Ullage Settling		Thrust in +x	2,10,6,14	5 sec. ss	-	-
Powered Descent	6 min.	Gimble Trim (Attitude Control)	5,2,1,6; 1,14,13,2	470 sec. pulsing (includes Powered descent and hover)	-	.1°; 763, 763 (y z), 10 ms
		.1° Limit Cycle about x	12,4,16,8	470 sec. pulsing (includes Powered descent and hover)	-	.1°; 9 (x), 10 ms

* NOTE: ss refers to steady-state or pulse widths greater than 1 second
** Perform six (6) such operations

***The column headed "L.C., # pulses/thruster (axes), P.W." is to be interpreted as follows: for example, 0.1°; 2, 2 (x,z), 10 ms is taken to mean: 0.1° limit cycle dead zone; 2, 2 (x,z) refers to 2 pulses per thruster about the x-axis and 2 pulses per thruster about the z-axis during the operation specified (four thrusters, firing in pairs, are used about each axis to maintain limit cycle).

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TABLE V (Continued)

TABLE (2) (continued)

MISSION PHASE	PHASE TIME	OPERATION	THRUSTERS	TIME OF OPERATION	COAST TIME BETWEEN FIRINGS	L.C., #PULSES/THRUSTER (AXES), P.W.
Powered Descent (cont.)		180° Rot. about x	12, 4 16, 8	1.19 sec. ss 1.19 sec. ss	34.8 sec.	-
		(2) 90° Rot. about y	5, 2 1, 6	1.19 sec. ss 1.19 sec. ss	16.8	-
Hover to Touchdown (manual control maneuvers)	2 min.	90° Rot. about x	12, 4 16, 8	4 sec. ss 4 sec. ss	0	-
		30° Rot. about y	5, 2 1, 6	2.3 sec. ss 2.3 sec. ss	0	-
		30° Rot. about z	1, 14 13, 2	2.3 sec. ss 2.3 sec. ss	0	-
		30° Rot. about y	5, 2 1, 6	2.3 sec. ss 2.3 sec. ss	0	-
		30° Rot. about z	1, 14 13, 2	2.3 sec. ss 2.3 sec. ss	0	-
		15° Rot. about x	12, 4 16, 8	1.8 sec. ss 1.8 sec. ss	0	-
ASCENT						
Powered Ascent	380 sec.	180° Rot. about x	12, 4 16, 8	.45 sec. .45 sec.	35.4 sec.	-
		Correct for 284 ft - lb	13, 2	190 sec. pulsing	-	.1°; 1225 -40 ms pulses, 40 ms on, 115 ms off
		Mom. Unbalance about z	9, 6	190 sec. pulsing	-	.1°; 1225 -40 ms pulses, 40 ms on, 115 ms off
		Correct for 211 ft - lb	5, 2	190 sec. pulsing	-	.1°; 910 - 40 ms pulses, 40 ms on, 168 ms off
		Mom. Unbalance about y	9, 14	190 sec. pulsing	-	.1°; 910 - 40 ms pulses, 40 ms on, 168 ms off
		.1° Limit Cycle about x	12,4,16,8	380 sec. pulsing	-	.1°; 84 (x), 10 ms
Ascent Contingency Stay	17.7 hrs.	5° Limit Cycle	12,4,16,8; 5,2,1,6; 1, 14, 13, 2	17.5 hrs. pulsing		5°; 290, 338, 672 (x, y, z), 10 ms
		(10) 90° Rot. about y	5, 2 1, 6	.22 sec. .22 sec.	17.8 sec.	.1°; 8, 30 (x, z), 10 ms
		(5) 90° Rot. about x	12, 4 16, 8	.22 sec. .22 sec.	17.8 sec.	.1°; 9, 30 (y z), 10 ms
		(5) 90° Rot. about z	1, 14 13, 2	.11 sec. .11 sec.	17.9 sec.	.1°; 8, 9, (x, y), 10 ms
Ullage Settling		Thrust in + x	10, 2	2.5 sec. ss	-	-

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TABLE V (Continued)

MISSION PHASE	PHASE TIME	OPERATION	THRUSTERS	TIME OF OPERATION	COAST TIME BETWEEN FIRINGS	L.C, # PULSES/THRUSTER (AXES), P.W.
ASCENT (cont.)						
Ascent Coast	58 min.	5° Limit Cycle	12,4,16,8; 5,2,1,6 1,14,13,2	58 min. pulsing	-	5°; 16, 20, 36 (x, y, z), 10 ms
		90° Rot. about y	5,2 1,6	.22 sec. .22 sec.	17.8 sec.	.1°; 6,24 (x, z), 10 ms
		90° Rot. about z	1,14 13,2	.11 sec. .11 sec.	17.9 sec.	.1°; 6, 7 (x, y), 10 ms
Mid-course correction, Rendezvous and Docking	44 min.	5° Limit Cycle	12,4,16,8; 5,2,1,6 1,14,13,2	35 min. pulsing	-	5°; 10, 12, 22 (x, y, z), 10 ms
	Rendezvous Time (sec.)					
	0	Trans. in + x	2,6,10,14	66.5 sec. ss	-	.1°; 20, 25, 80 (x, y, z), 10 ms
	483	Trans. in - x	1,5,9,13	2.4 sec. ss	-	.1°; 1, 1, 3 (x, y, z), 10 ms
	486	Trans. in - z	3, 1,	13.8 sec. ss	-	.1°; 4, 5, 17 (x, y, z), 10 ms
	829	Trans. in - x	1,5,9,13	26.6 sec. ss	-	.1°; 8, 10, 32 (x, y, z), 10 ms
	856	Trans. in - z	3, 15	23.3 sec. ss	-	.1°; 7, 9, 28 (x, y, z), 10 ms
	1148	Trans. in - x	1,5,9,13	5.0 sec. ss	-	.1°; 2, 2, 6 (x, y, z), 10 ms
	1153	Trans. in - z	3, 15	30.4 sec. ss	-	.1°; 9, 11, 36 (x, y, z), 10 ms
	1408	Trans. in - x	1,5,9,13	3.6 sec. ss	-	.1°; 1, 1, 4 (x, y, z), 10 ms
	1412	Trans. in - z	3, 15	27.5 sec. ss	-	.1°; 8, 10, 33 (x, y, z), 10 ms
	2012	Trans. in + y	12, 16	1.8 sec. ss	-	.1°; 1, 1, 3 (x, y, z), 10 ms
	Docked2400	Trans. in + z	7, 11	11.0 sec. ss	-	.1°; 4, 5, 17 (x, y, z), 10 ms

* NOTE: ss refers to steady-state or pulse widths greater than 1 second

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TABLE VI

ENVIRONMENTAL TEST REQUIREMENTS FOR THRUST CHAMBER CLUSTER ASSEMBLIES

MISSION PHASE	VIBRATION MODE & SHOCK	CYCLES OR TIME	INTENSITY OR RATE	REMARKS
I. Launch Boost (Input to Grumman Support Structure)	Sinusoidal	5-18.5 cps 18.5-250 cps 250-377 cps 377-2000 cps	0.20 inch D.A. 3.5g .0011 inch D.A. 8.0g	One Sweep Rise and Fall at 3 octaves/ minute for each of 3 major axes.
	Random	10-23 cps 23-80 cps 80-105 cps 105-950 cps 950-1250 cps 1250-2000 cps	12 db/octave rise to $.025g^2$/cps 12 db/octave rise to $.075g^2$/cps 12 db/octave roll off $.025g^2$/cps	Five minutes of Random Vibration for each of 3 major axes.
II. Lunar Excursion (Input to Grumman Support Structure)	Sinusoidal	5-17.4 cps 17.4-317 cps 317-511 cps 511-2000 cps	.13 in. D.A. 2.0g .00039 in. D.A. 5.2g	One Sweep Rise and Fall at $\frac{1}{2}$ Octave/ minute for each of 3 major axes.
	Random	10-20 cps 20-100 cps 100-119 cps 119-2000 cps	12 db/octave rise to $.034g^2$/cps 12 db/octave roll off $.017g^2$/cps	Twenty-one minutes of Random Vibration for each of 3 major axes.
	Shock	11 $\pm$ 1 ms Rise 1 $\pm$ 1 ms Decay	15g	Sawtooth shock three pulses in each orthogonal direction for a total of 18 pulses.

TABLE VII

ENVIRONMENTAL REQUIREMENTS FOR QUALIFICATION TEST OF PROPELLANT INLET FILTERS

Test Description	Intensity or Rate	Cycles or Time	Remarks
Shock	In accordance with MIL-STD-810 (USAF) 14 June 1962	Method 516, Procedure I	Modify to sawtooth pulse; 45g peak value; 11 ± 1 ms rise time, 1 ± 1 ms decay time.
Vibration Sinusoidal	0.5 inch D.A. or ± 20g (whichever is lower)	5-3000 cps	Vibration shall be applied along each of the three mutually perpendicular axes. One sweep increasing frequency and one sweep decreasing frequency at $\frac{1}{2}$ octave/min.
Vibration Random	12 db/oct. rise to $0.6g^2$/cps Constant $0.6g^2$/cps 12 db/oct. roll-off	50-100 cps 100-1000 cps 1000-2000 cps	10 minutes in each orthogonal direction for a total of 30 minutes.
Sustained Acceleration	X Axis: 13.5g Lateral: 13.5g	1 minute/axis	Applied separately along each of three mutually perpendicular axes.
Shock	15g sawtooth	11 ± 1 ms rise 1 ± 1 ms decay	3 shocks in each direction along each orthogonal axis for a total of 18 shocks

TABLE VIIB

REQUIREMENTS FOR ACCEPTANCE TEST OF INSTRUMENTATION AND FILTERS

Test Description	Intensity or Rate	Cycles or Time	Remarks
Pressure	1 x 10^{-5} mm Hg	4 hours	Operation per approved vendor duty cycle.
Electromagnetic Interference	In accordance with Grumman Specification LSP-530-001.		
Vibration Random	12 db/oct. rise to $0.38g^2$/cps $0.38g^2$/cps constant 12 db/oct. roll-off	50-100 cps 100-1000 cps 1000-2000 cps	Operation per approved vendor duty cycle. 5 minutes in each orthogonal axis for a total of 15 minutes.

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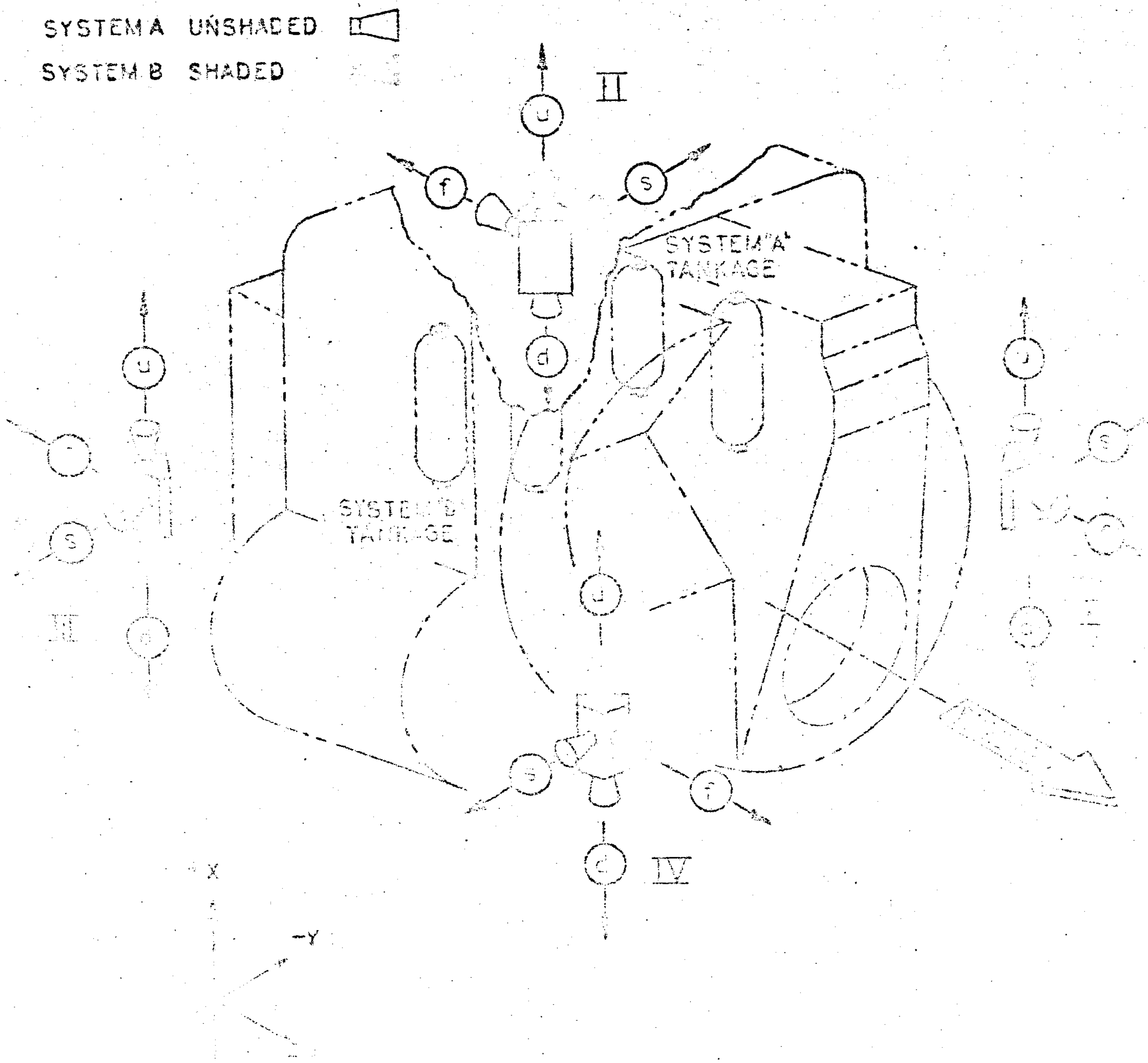
TABLE IX

Component	Quantity Per PS/TCA	Total Weight (lb)
A. Thrust Chamber Assembly	16	In accordance with NAA Spec. MC 901-0004
B. TCA Cluster Mount	4	7.12
C. Misc. Cluster Hardware (Brackets, screws, etc.)		0.56
D. Instrumentation Brackets, pigtails, etc.		0.60
E. Chamber Pressure Transducer	16	6
F. Injector Head Temperature Transducer	16	1
G. Propellant Pressure Transducer	16	5
H. Propellant Filter	16	3.2



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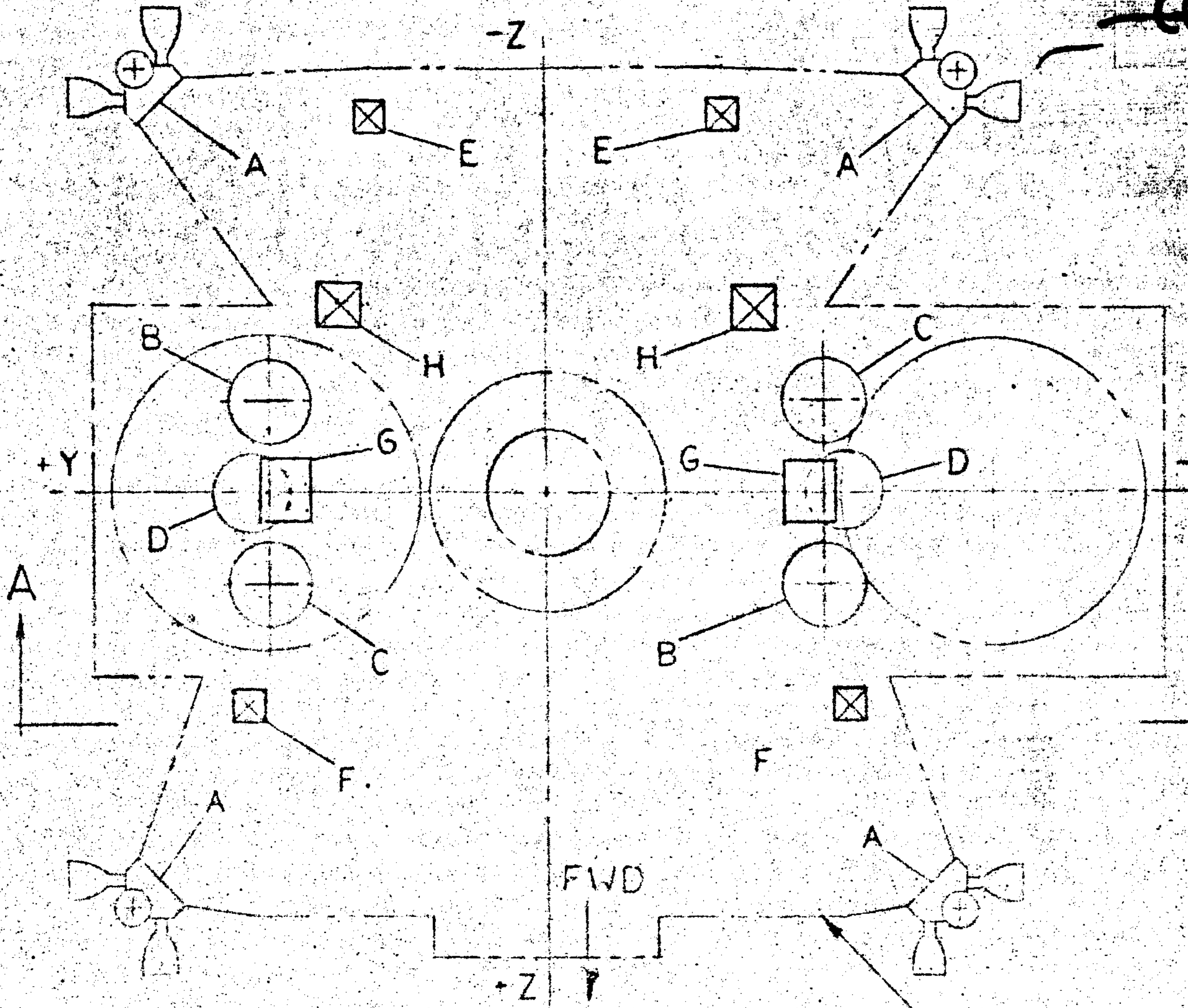

VIEW LOOKING DOWN

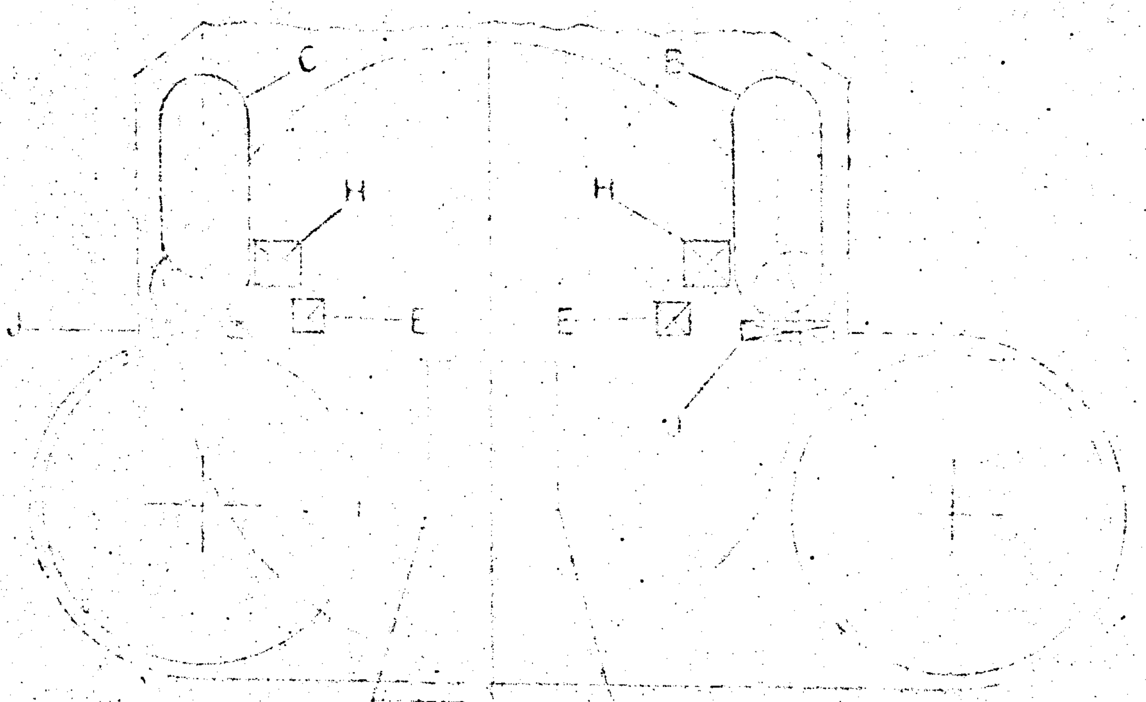

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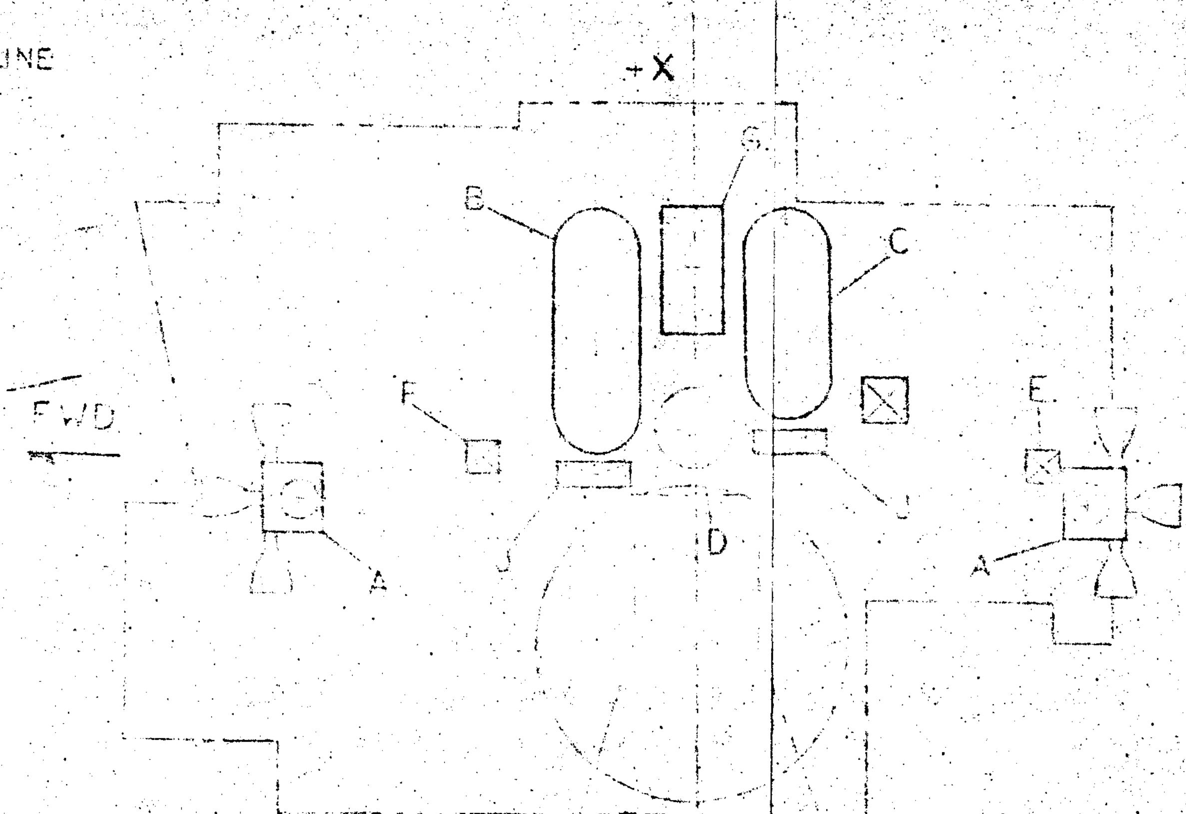
FIGURE 3

ITEM	COMPONENT
A	T.C.A. CLUSTER
B	OXIDIZER TANK
C	FUEL TANK
D	HELIUM TANK
E	ISOLATION VALVES-AFT
F	ISOLATION VALVES-FWD
G	REGULATING COMPLEX
H	INTERCON/CROSSFEED VALVES
J	MAIN S/O VALVES & PROPELLANT DISCONNECTS

RCS COMPONENT LOCATIONS



VIEW LOOKING INBOARD - L.H. SIDE